Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

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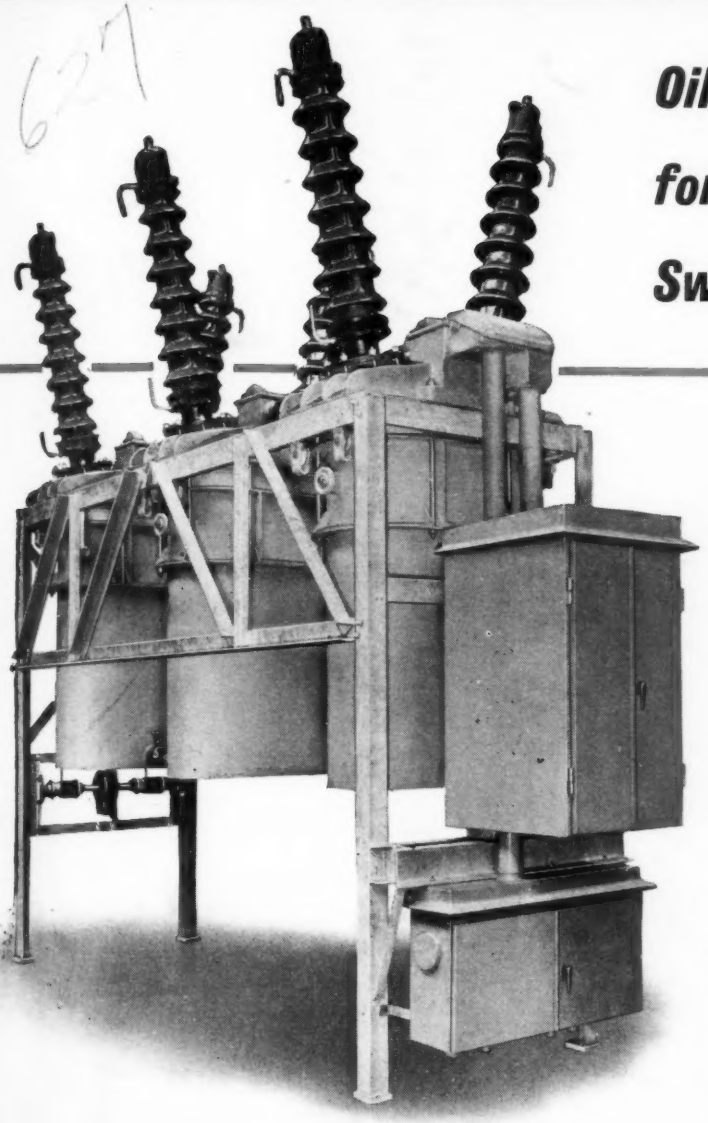

Oil Circuit breakers for Outdoor Switching Stations

TYPE OKG4
Ratings 66 kV & 88 kV
Current up to 1200 Amps
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Closing can be by hand-wound or motor-wound spring, solenoid or pneumatic mechanism. Specially designed oval shaped tanks give added strength and reduced oil capacity.

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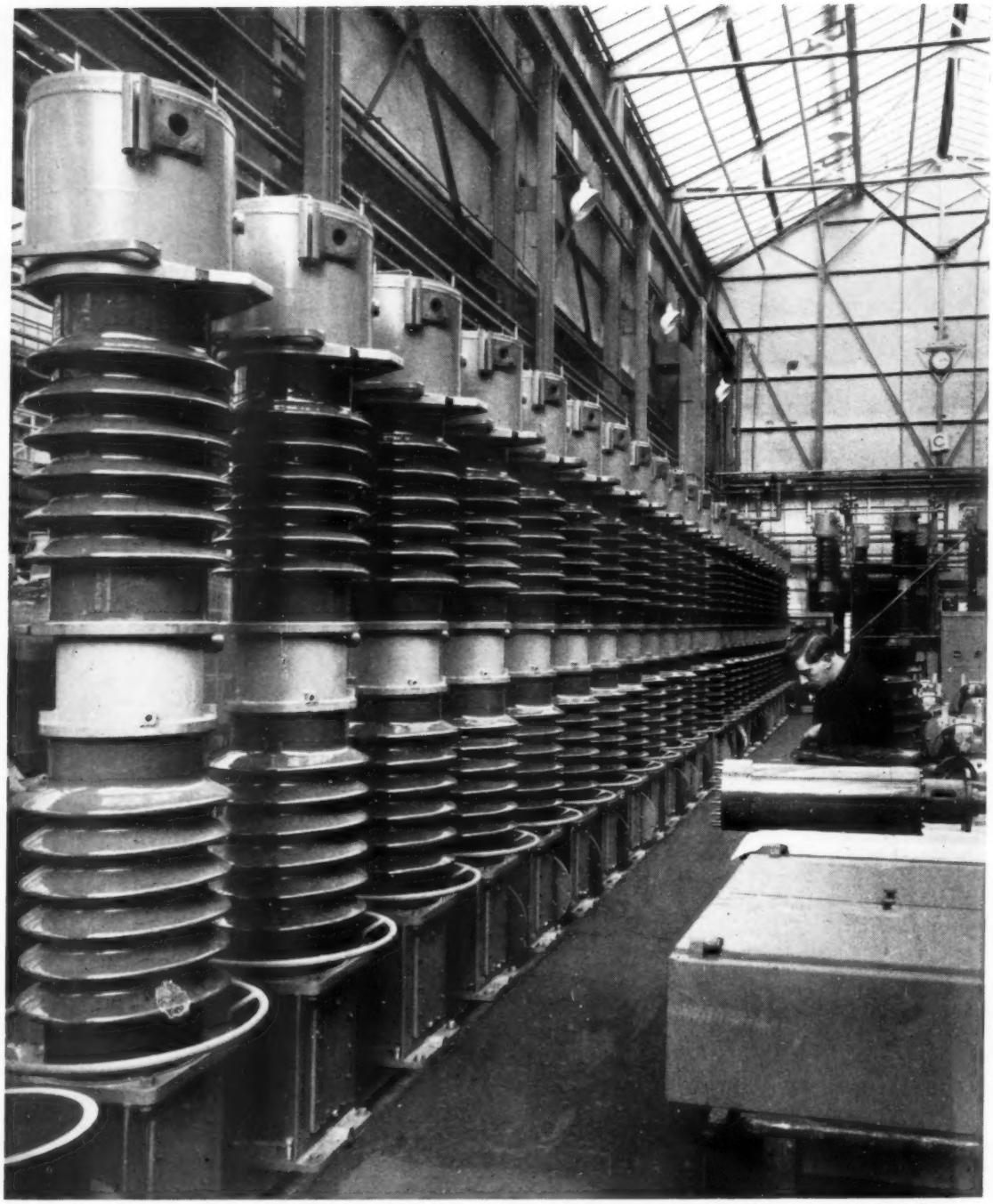

66-kV small-oil-volume circuit-breakers

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for Hydro-electric
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The Anti-vacuum Valve

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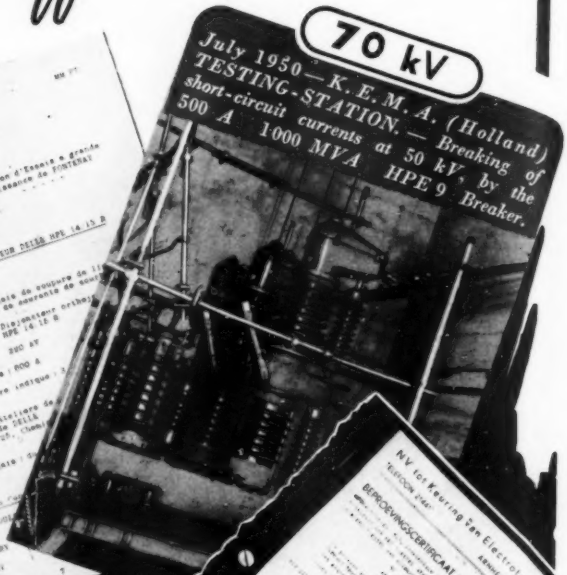
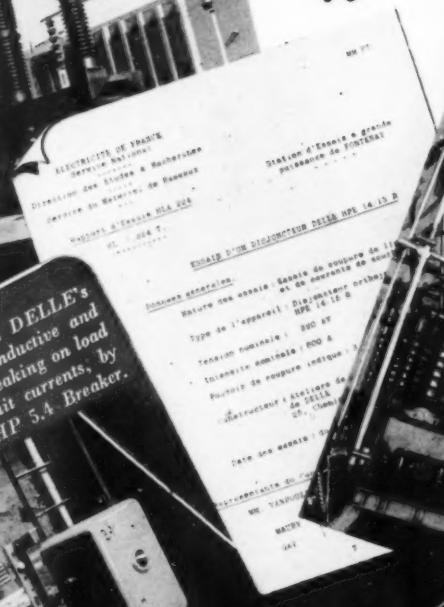
70 kV

July 1950 — K. E. M. A. (Holland) TESTING-STATION. — Breaking of short-circuit currents at 50 kV, by the 500 *A* 1000 *MVA* HPE 9 Breaker.



15 kV

May 1949 — ATELIERS DE DELLE's TESTING-STATION. — Inductive and Capacitive current breaks, breaking on load and breaking of short-circuit currents, by the 320 *A* 125 *MVA* HP 5.4 Breaker.



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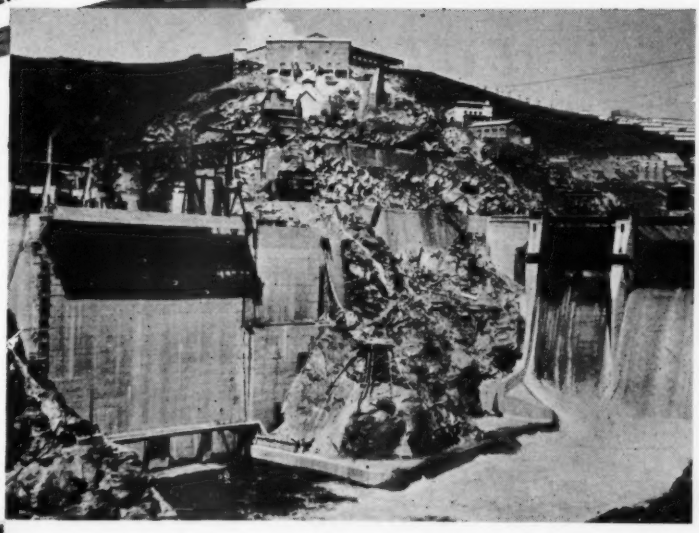
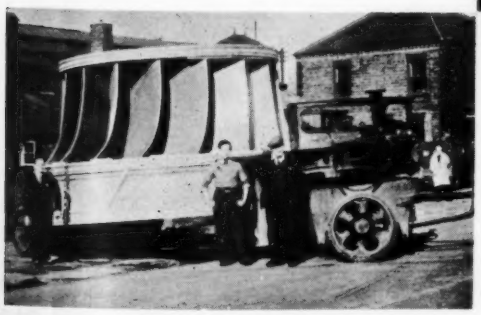
Each runner is 4.4 metres (14 ft. 5 in.) diameter, weighs 47 tons and has 18 cast steel blades welded to cast steel hub and band with welded-on protection of stainless steel They are believed to be the largest fabricated runners yet built in Europe.





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View of interior of power house over two low head Armfield Francis turbines. Each turbine drives a 45 KW alternator and is independently governed.
The sets operate in parallel with each other and with a further Hydro-Electric and Diesel installation some two miles downstream. This installation was recently completed to the order of A. F. Wallace, Esq., of Candacraig.
Consultants—Messrs. Griffin Smith & Partners Ltd.

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THE ARMFIELD HYDRAULIC ENGINEERING CO. LTD., RINGWOOD, HAMPSHIRE, ENGLAND

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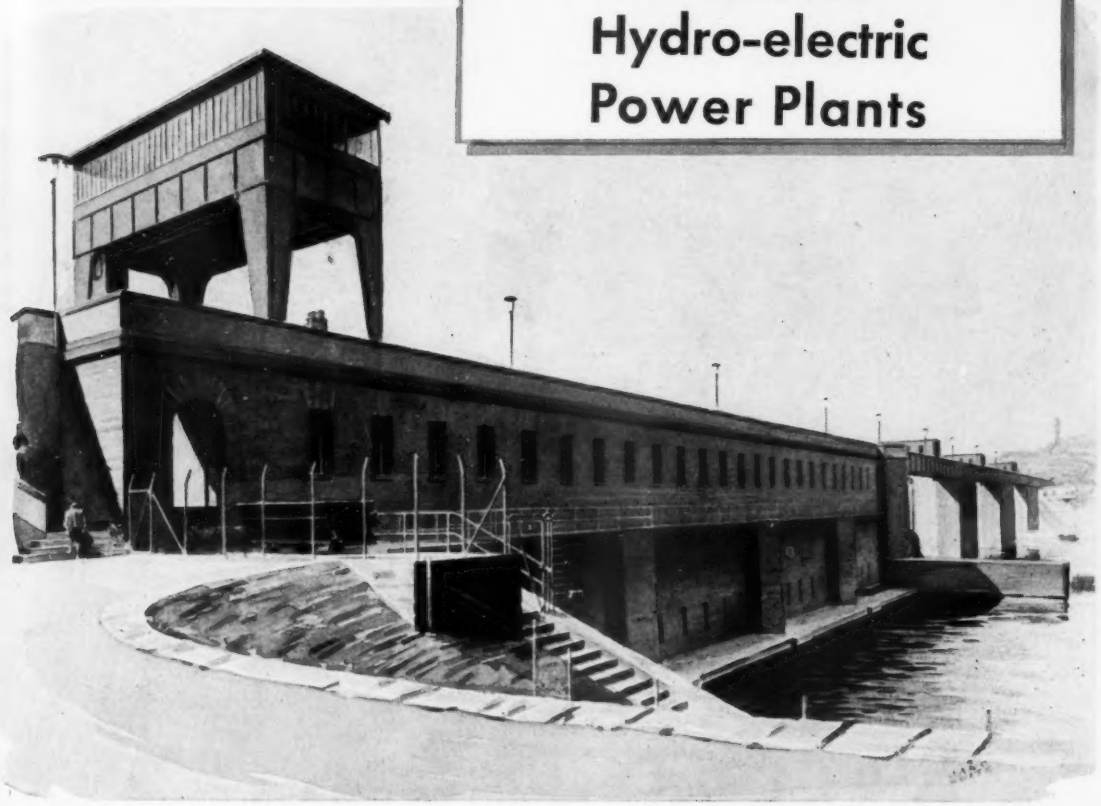
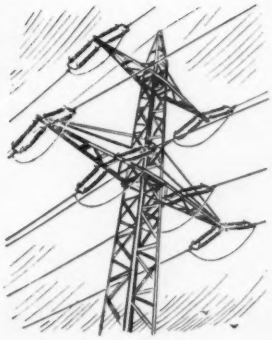
AEG

Hydro-electric Power Plants



For sixty years the AEG have been designing and building plants for the generation and transmission of hydro-electric energy. Billions of kilowatthours are generated year in year out by AEG water-wheel generators, transmitted and distributed over power line systems erected by the AEG.

Of the 67 hydro-generators ordered since 1946, of a rating up to 45,000 kVA, thirty-one units have been built and commissioned.



Experienced AEG engineers will be pleased to help you in consultation, planning and erection of hydro-electric development projects.

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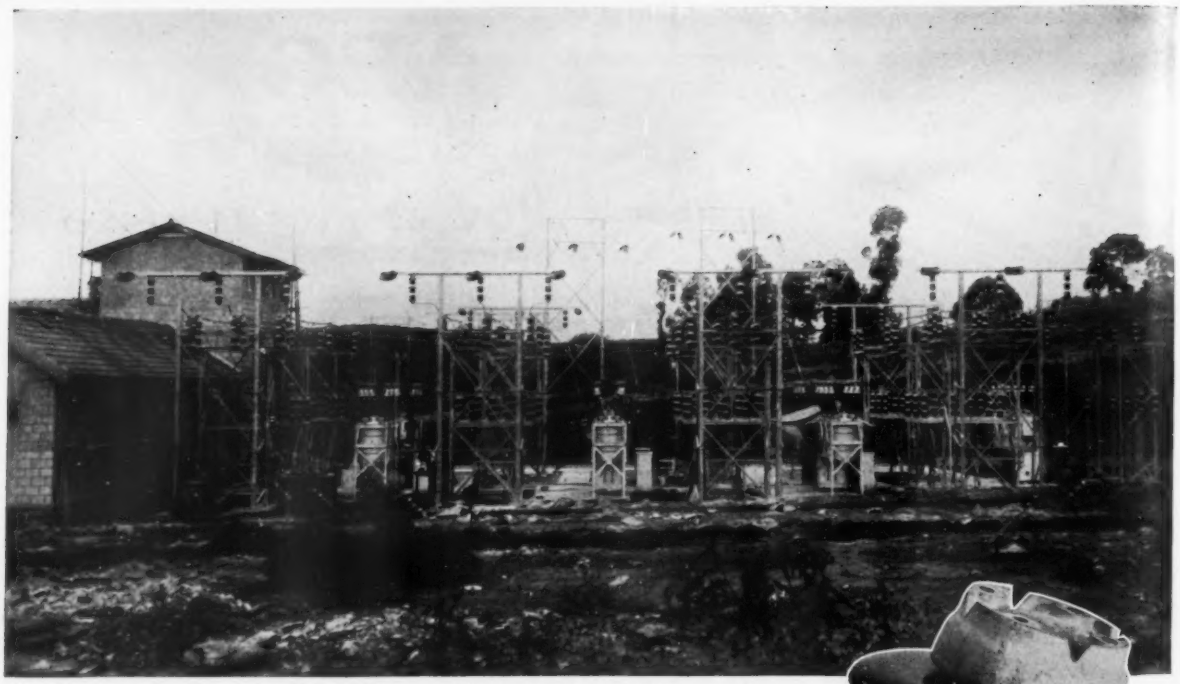

(Photograph reproduced by courtesy of Messrs. Metropolitan Vickers Electrical Co. Ltd.)

The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

S.P.P. POST INSULATORS were specified for all the 66kV outdoor switchgear on the Pallivasal Hydro Electric Scheme

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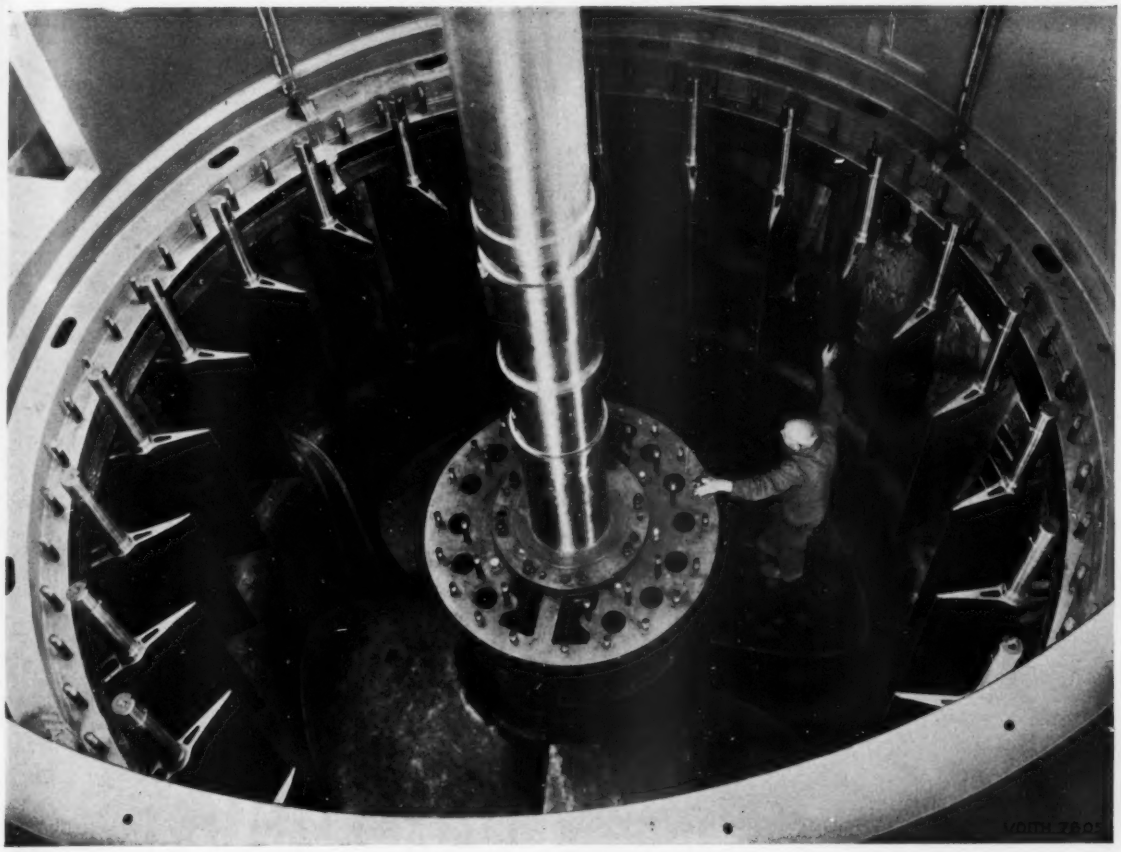

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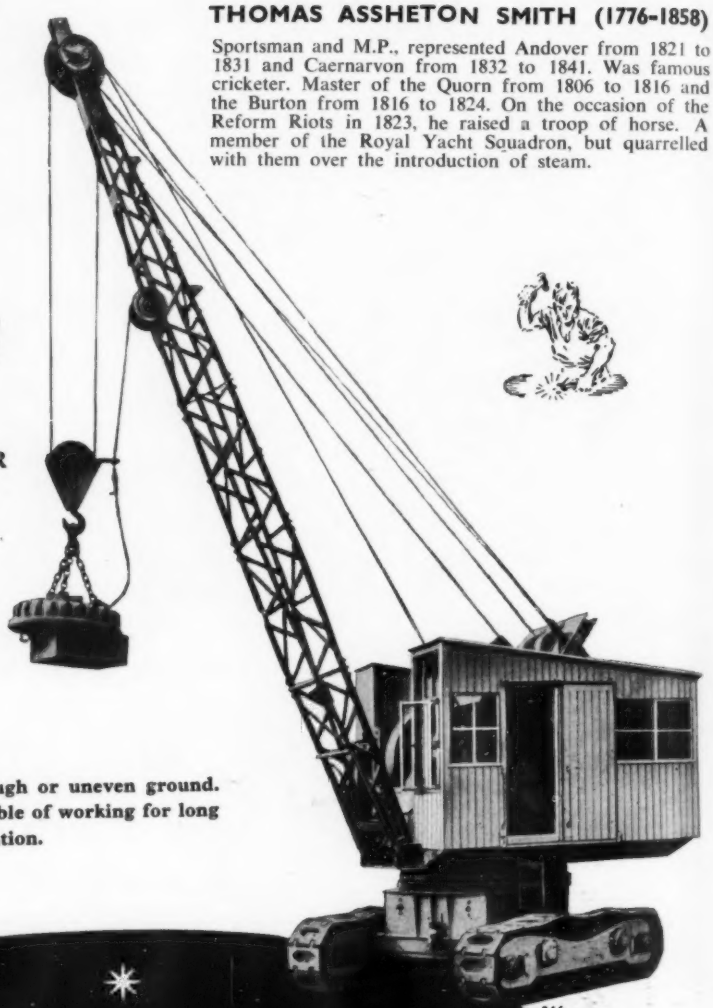

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Smiths of Rodley

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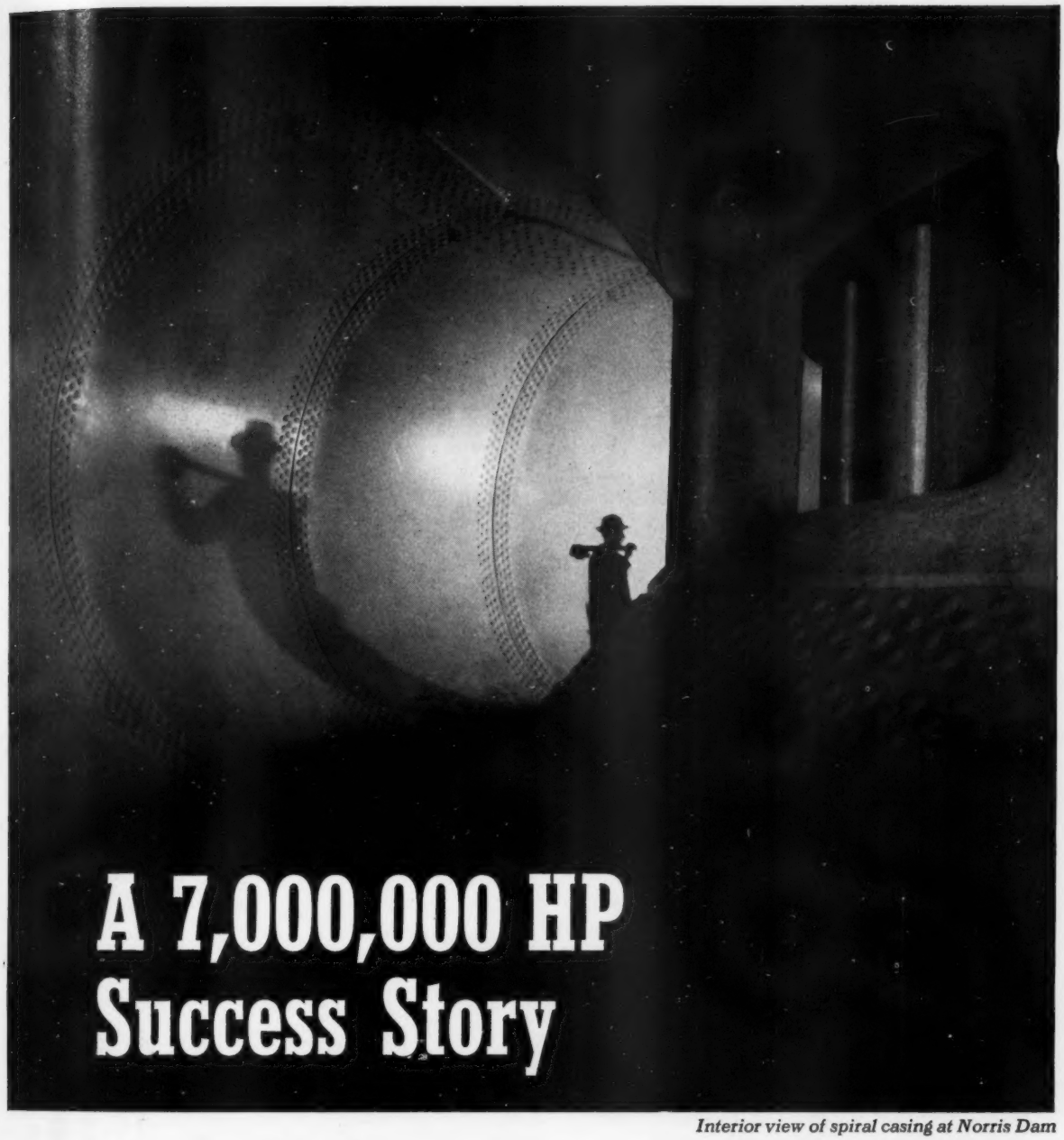

A 7,000,000 HP Success Story

Interior view of spiral casing at Norris Dam

Achievements of Newport News personnel in designing and building water power equipment during the past thirty years reflect a high integration of skill and production facilities.

Answering demands for hydraulic turbines rated as high as 165,000 horsepower and as low as 500 horsepower, this trained organization has successfully filled contracts with an aggregate rated output in excess of 7,000,000 horsepower.

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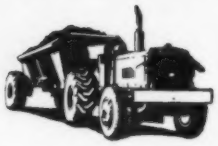

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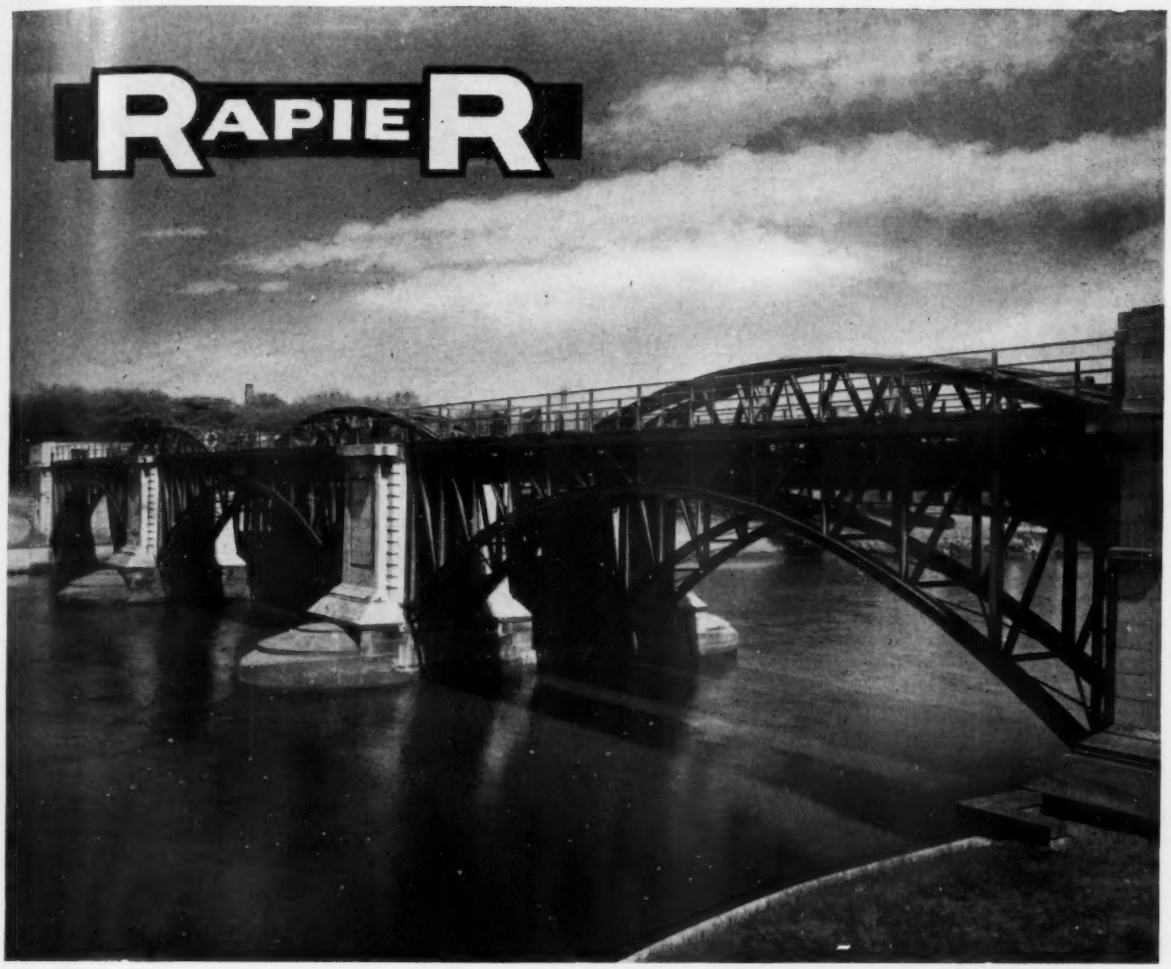

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RapieR Gates control flood water and retain the high tide level on the River Clyde in Glasgow. The installation includes three 80-feet span gates, 12-feet deep with bridge work and electric operating gears. The gates automatically turn under the arches in the fully raised positions.

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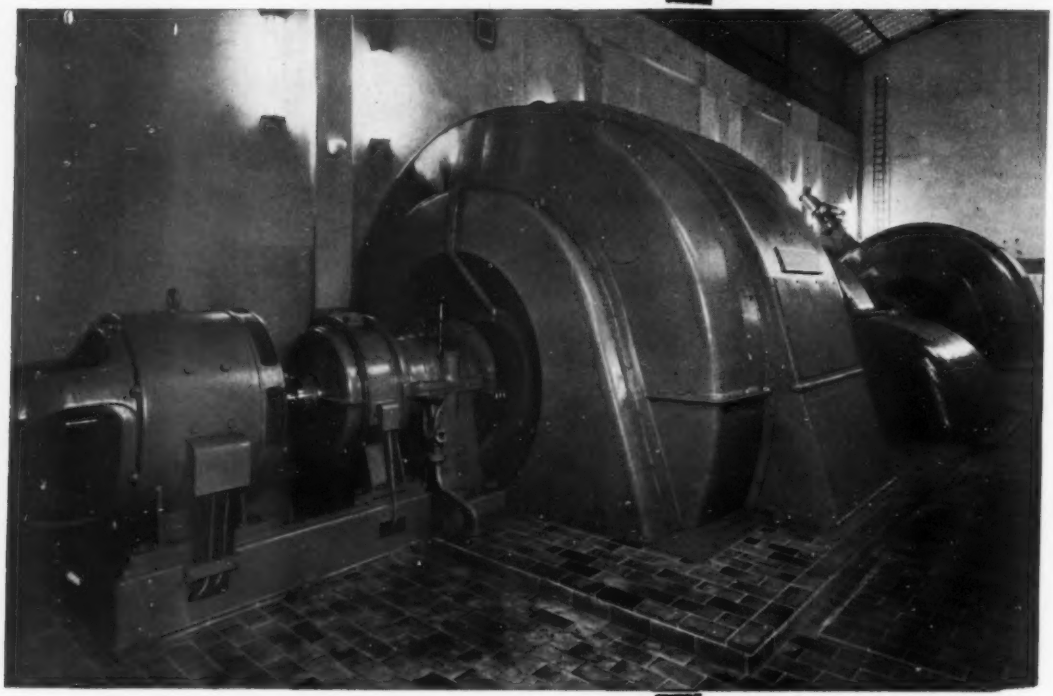

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Machine hall of Calancasca underground power station, Switzerland, showing the two Brown Boveri horizontal-shaft generators each rated 13,500 kVA, 10,000 V, 50 c/s, 500 r.p.m.

Generators

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Lightning arresters

Protective and regulating equipment

Control room equipment

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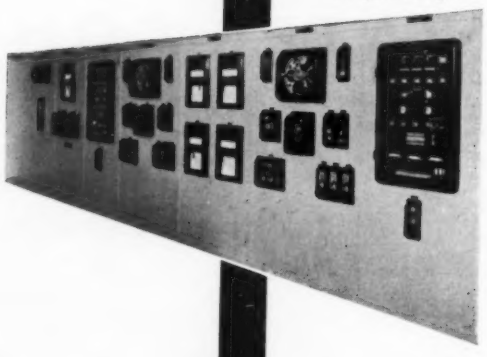
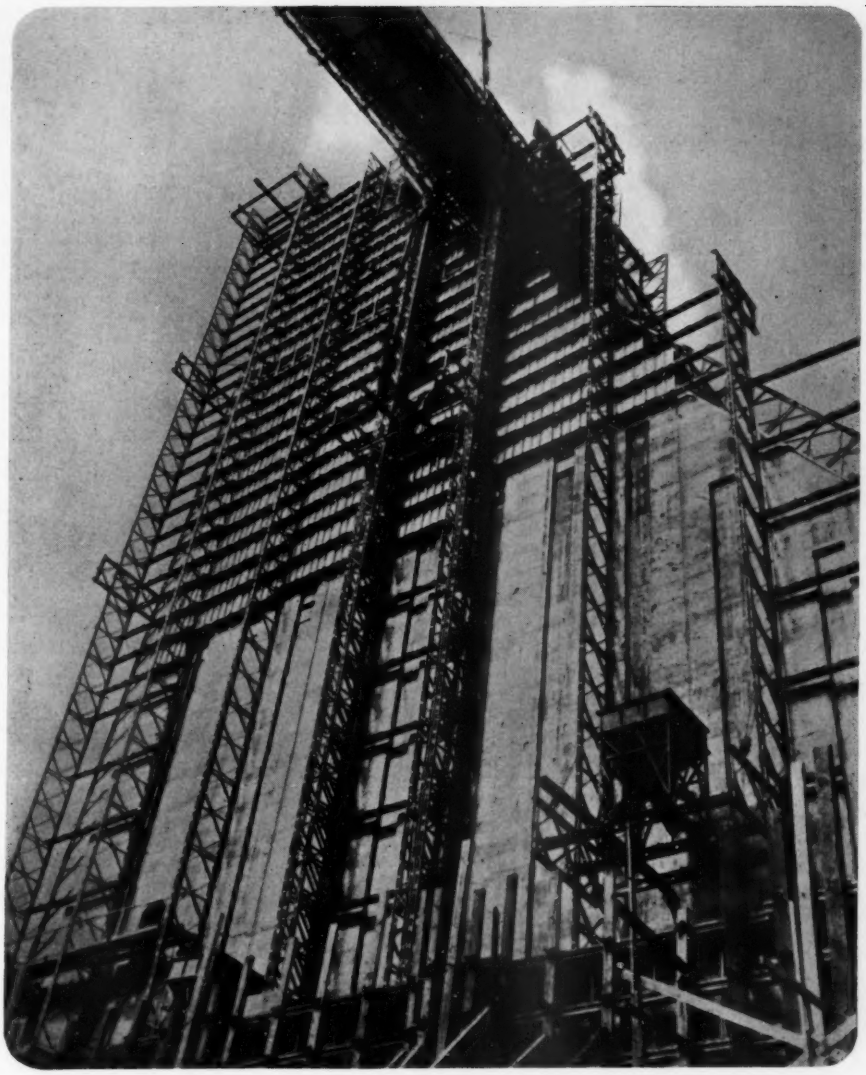


This relay board in the control room contains the regulating and protective apparatus for the generators and the outgoing lines.

BROWN, BOVERI & CO., LTD., BADEN SWITZERLAND



Photograph by courtesy of the Ontario Hydro Electric Commission

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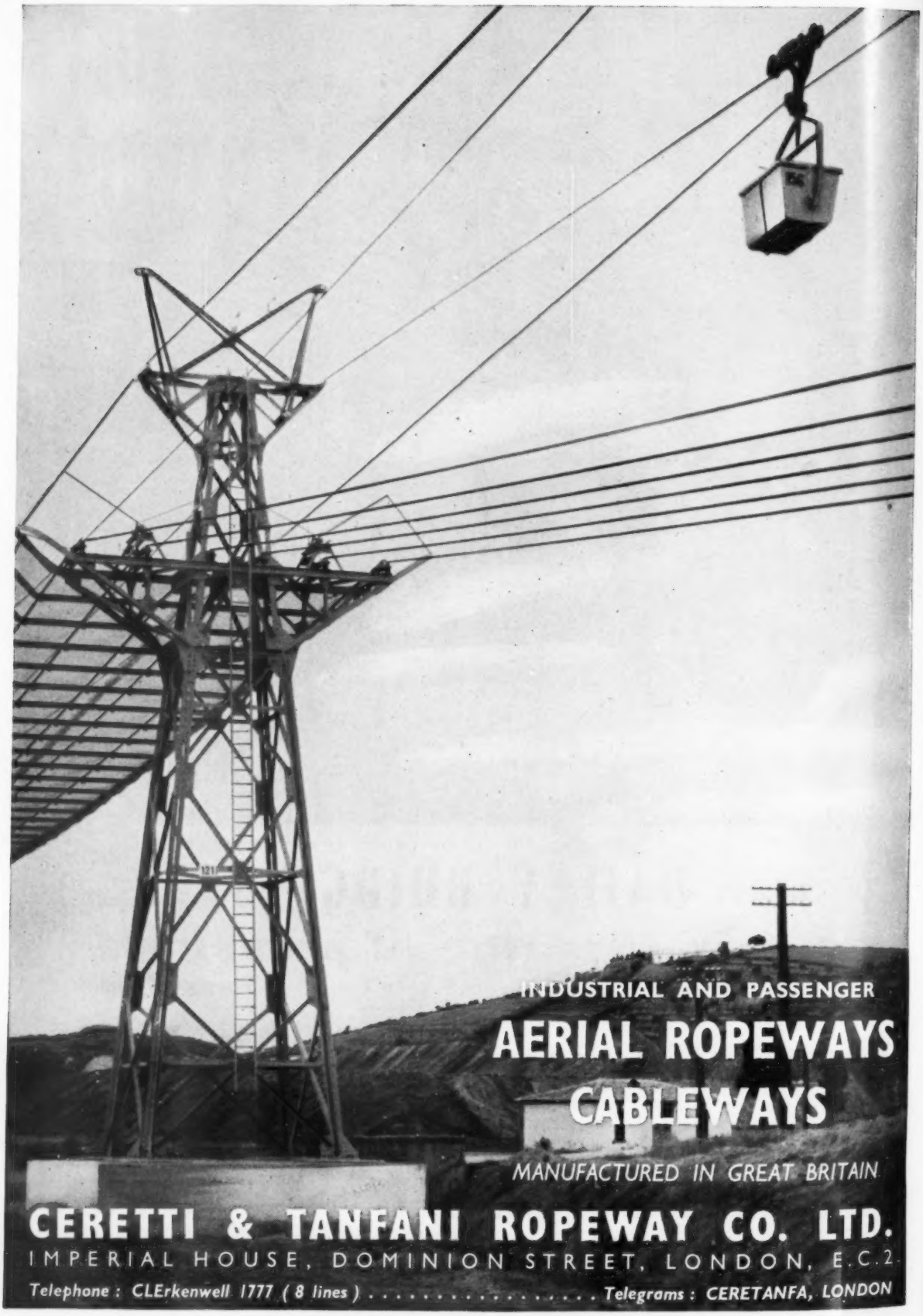
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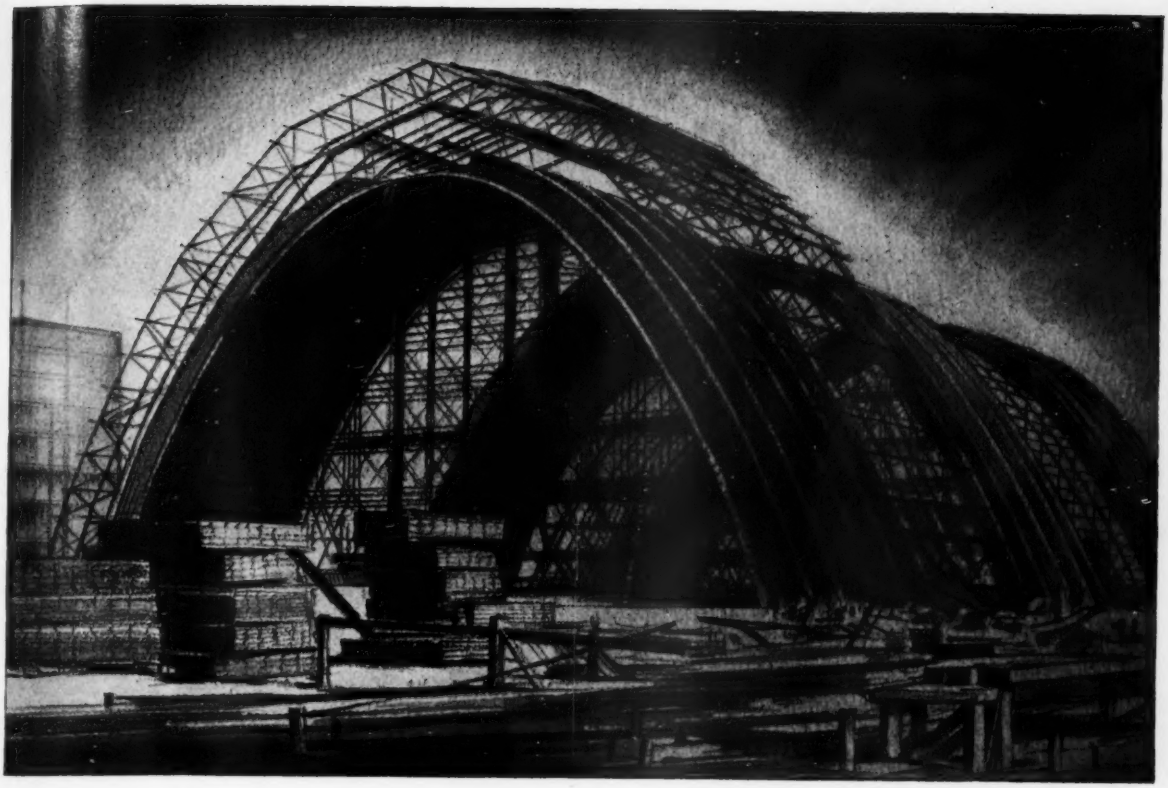

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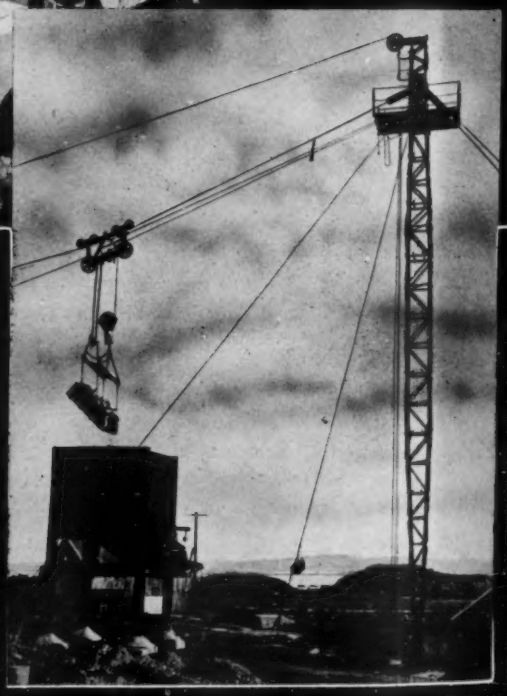

Giant hydro-electric schemes in all parts of the world make use of BRECO Aerial Ropeways and Cableways.

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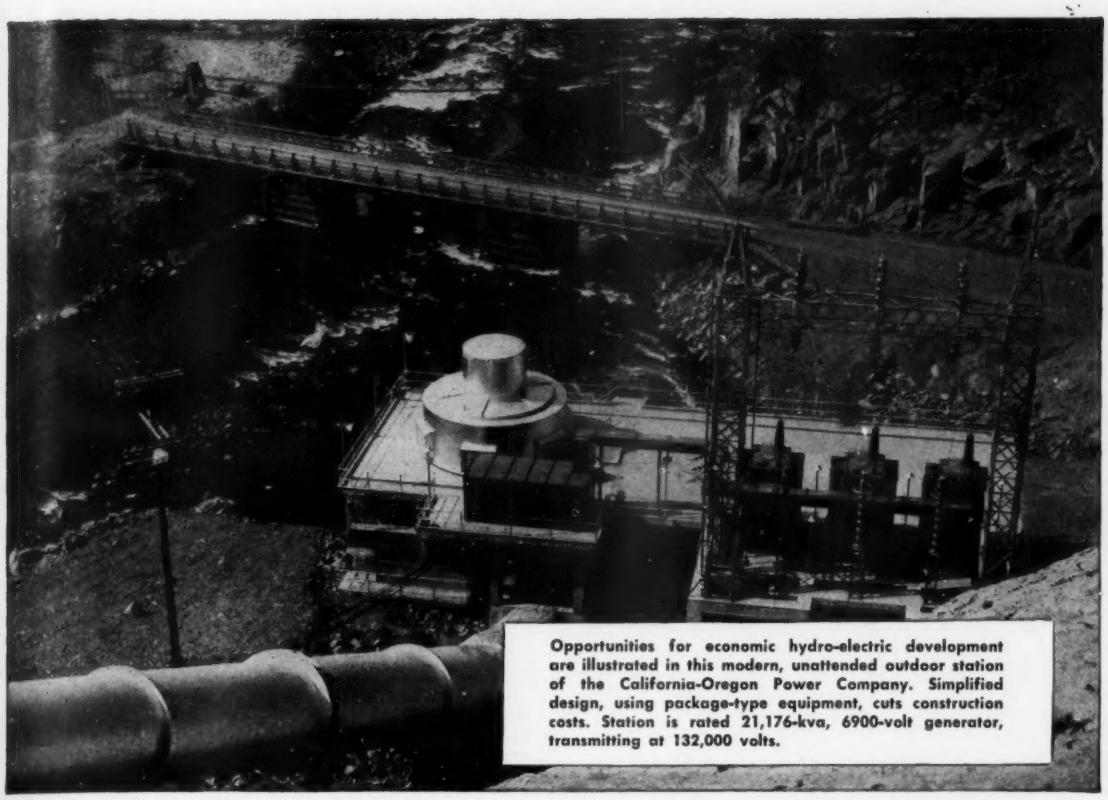
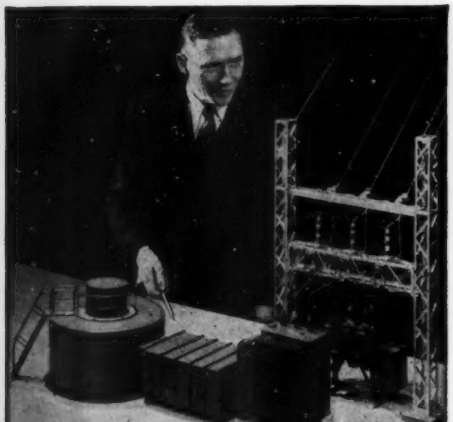


Opportunities for economic hydro-electric development are illustrated in this modern, unattended outdoor station of the California-Oregon Power Company. Simplified design, using package-type equipment, cuts construction costs. Station is rated 21,176-kva, 6900-volt generator, transmitting at 132,000 volts.

Automatic stations spark new interest in development of marginal hydro-electric sites



One of several package-type electrical equipments for hydro-electric stations, this model is being inspected by J. B. McClure, Manager, G-E Power Generation Div. Equipment design is completely co-ordinated, simplifying installation.

With low operating costs and simplified modern construction, small hydro-electric stations can be profitable investments

At a time when larger and larger generating stations tend to hold the spotlight as an obvious answer to growing demands for power, electric utilities are showing marked interest in small, unattended hydro-electric developments.

The reasons may be found in the increased opportunities for economic construction and operation offered through modern, factory-assembled equipments and proved methods of automatic control.

Engineered by General Electric, compact, package-type electrical equipment for hydro-electric stations is readily adaptable to remote control automatic or semi-automatic operation.

Designed around a simple line-up of hydraulic turbine operated generator, metal-clad switchgear, power transformer and outdoor station structure, they can be shipped in a minimum of sub-assemblies to simplify installation and reduce expense. In many cases, advantage can be taken of low cost outdoor station construction.

Water power is one of the great resources of a nation. Modern engineering advances, typified in these dependable, factory-assembled equipments, will speed its development to the maximum possible economic limits. See your G-E representative for more information. Or write: International General Electric Co., Central Station Sales, 570 Lexington Ave., New York 22, N.Y., U.S.A.

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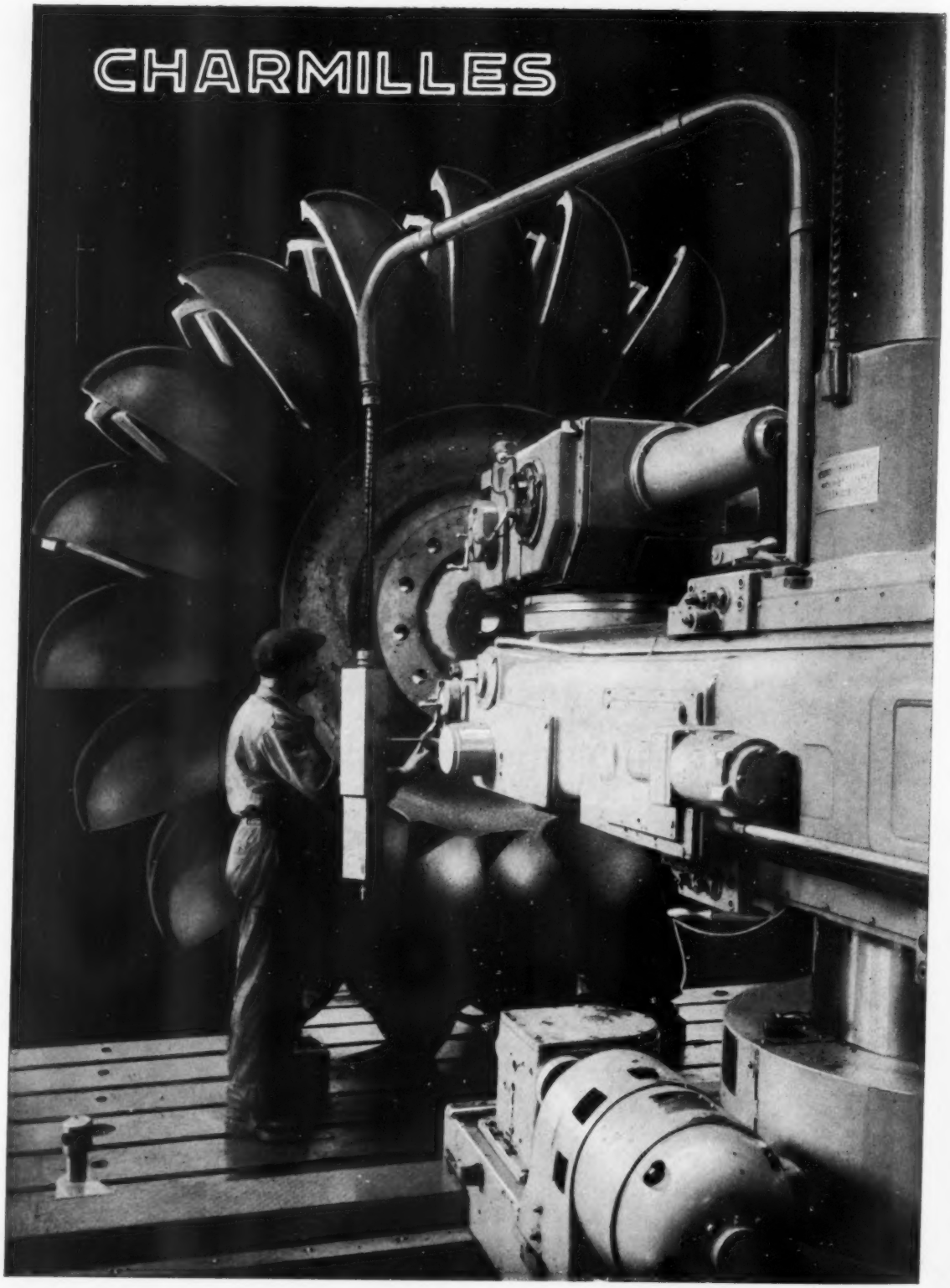

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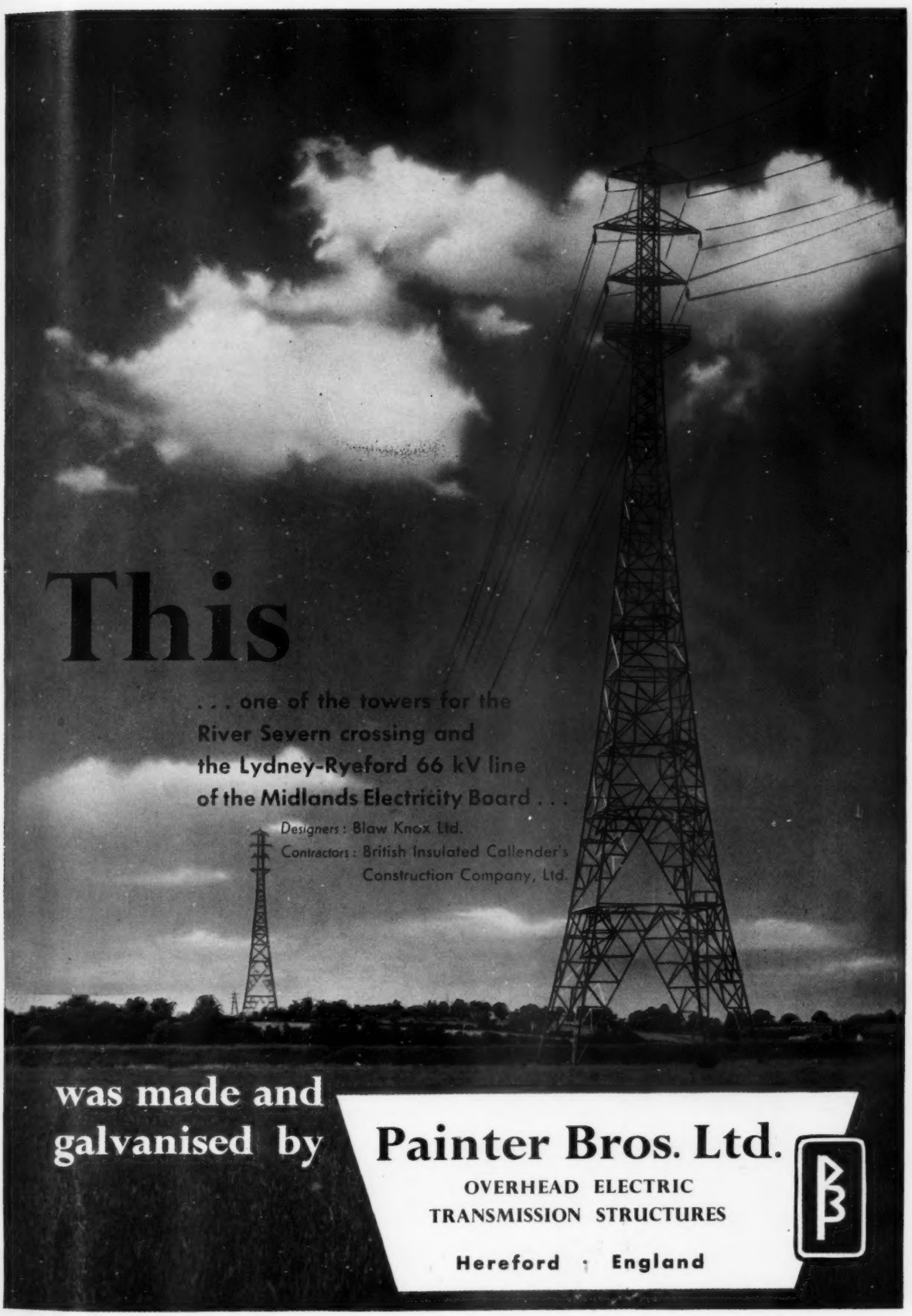
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. . . one of the towers for the
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Contractors : British Insulated Callender's
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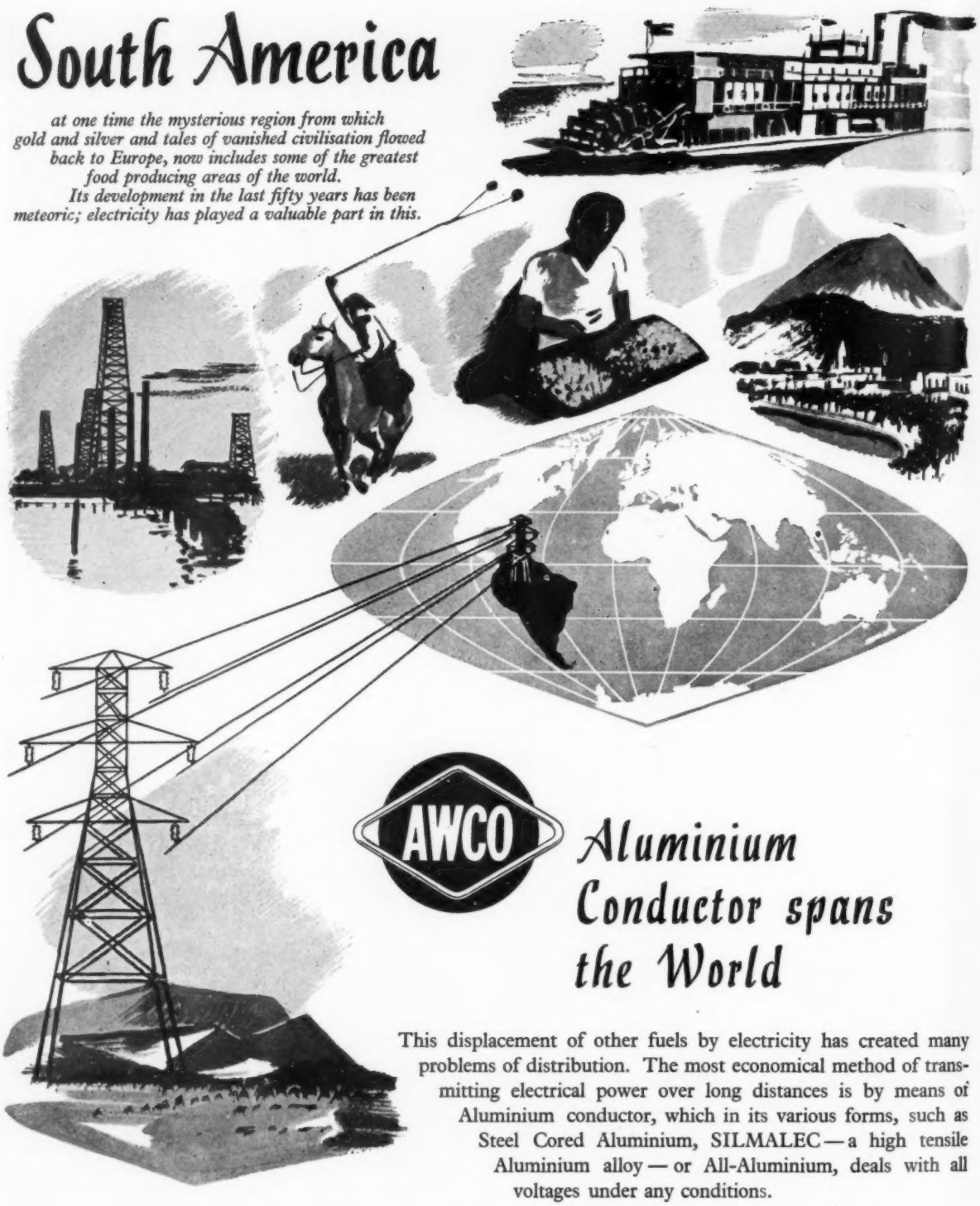
Its development in the last fifty years has been meteoric; electricity has played a valuable part in this.



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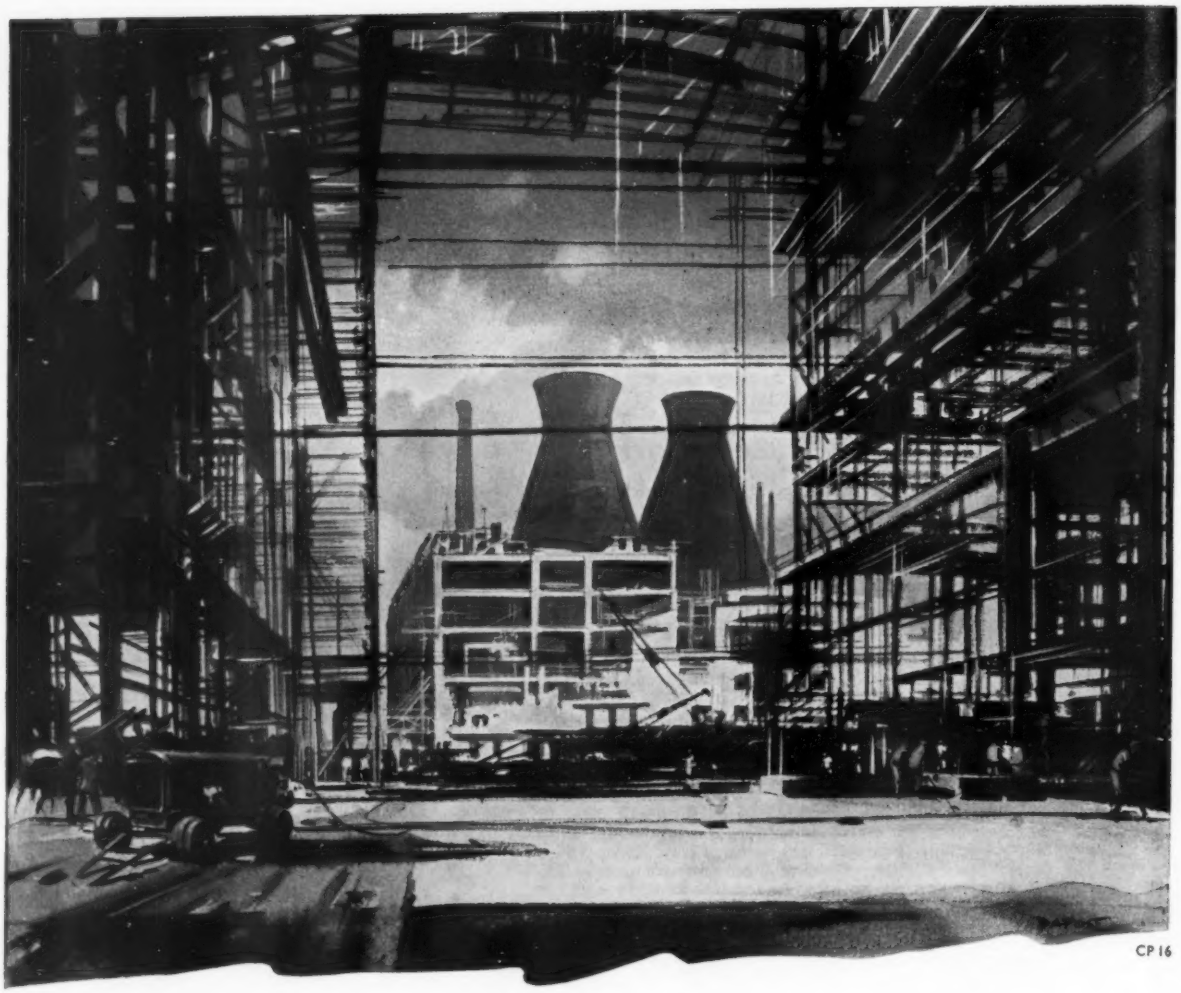

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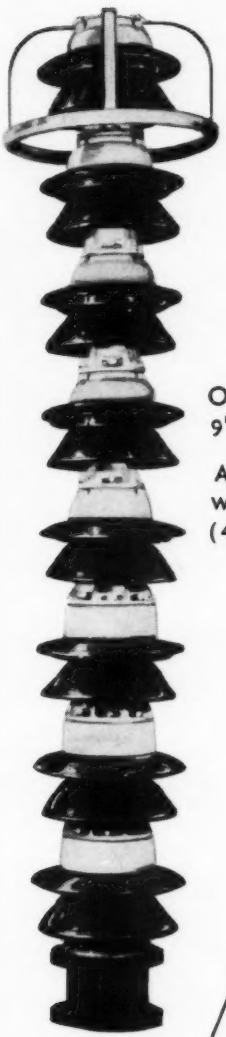

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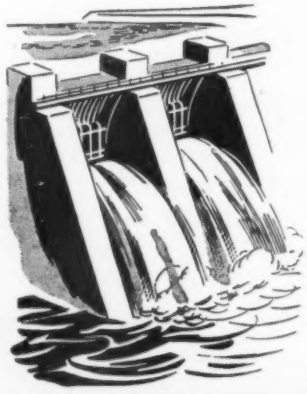

NEARLY thirty years experience in design and manufacture and an output of **eighteen million kVA** of transformers in all types and sizes, including some of the world's largest. Such figures are a true measure of excellence, for they could have been achieved only by the maintenance of the highest standard in design and construction and on a basis of long and reliable service.

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Twenty-four Aveling-Barford 4½ cu. yd. Shuttle Dumpers, some of which have logged over 8,000 working hours, are making a big contribution to the construction of the Daer Valley dam, some 45 miles south of Glasgow. These machines have been used right from the start — nearly five years ago — when they assisted in stripping the area of 350,000 cubic yards of peat. Since then they have been used continuously for transporting concrete aggregates, mixed concrete and excavated rock. Their day in, day out reliability and outstanding manœuvrability has done much to speed the completion of this important project.

Write for Publication No. i529/43.

The spillway head of the Daer Valley dam — the largest of its type in Britain — with the projected reservoir in the background.

AVELING - BARFORD

4½ YARD DUMPER

Photographs by courtesy of the Daer Water Board and Messrs. Binnie, Deacon and Gourley, Consulting Engineers.

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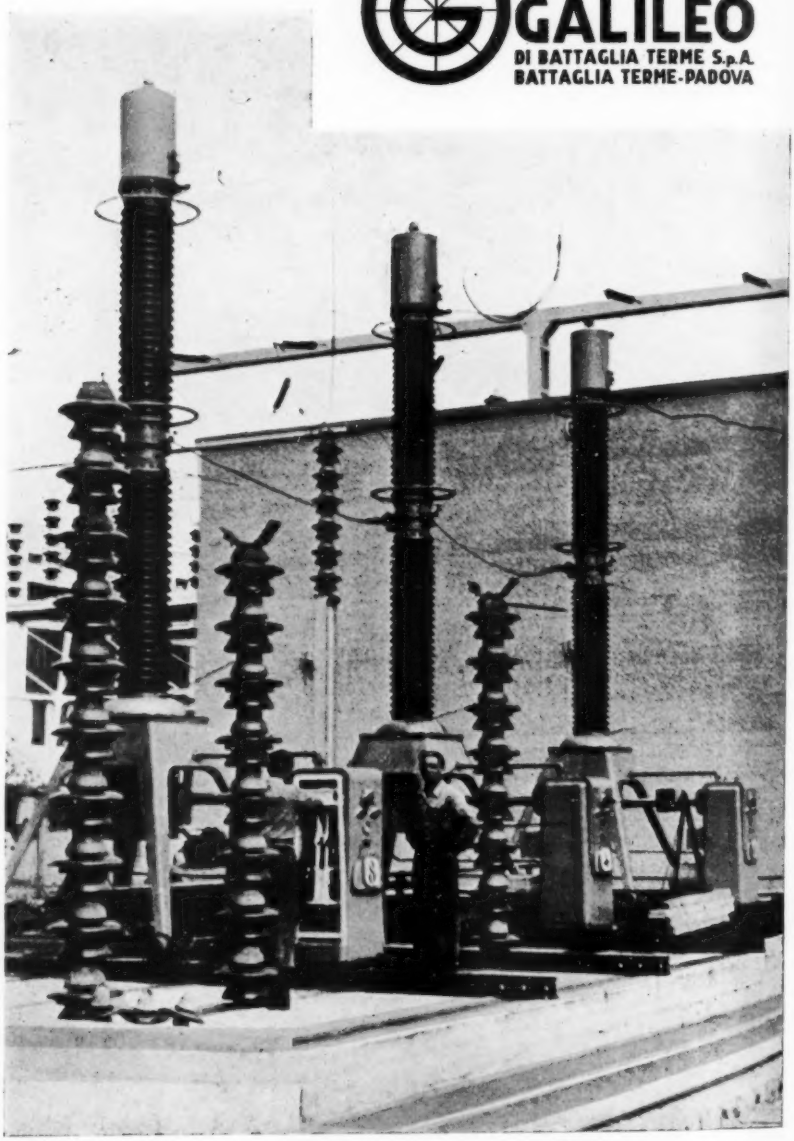

The illustration shows :
Switchgear type OCERD 220 photographed during a test for maximum load, made with favourable results at the test station of Messrs. Eléctricité de France at Fontenay aux Roses (Paris).

Specification of the switchgear :
OCERD 220-225 kV
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5000 MVA

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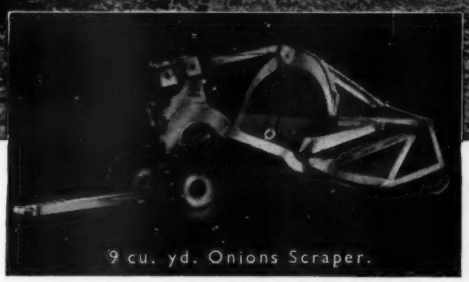
Onions Scrapers are way ahead

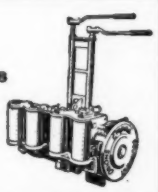
The 13 cu. yd. Onions Scraper in action with the Vickers VR·180 Tractor



9 cu. yd. Onions Scraper.

Onions Scrapers are made in **3, 4, 6, 9, 13 and 20 cu. yd. sizes. Tractors equipped with Onions Scrapers give faster production and lower operating costs. 6 cu. yd. models and over are equipped with a 3-piece cutting edge tipped with wear resisting alloy; two sets of end pieces are provided for either digging or levelling.**

ONIONS CONTROL UNITS for finger-tip control of heavy earth-moving equipment.



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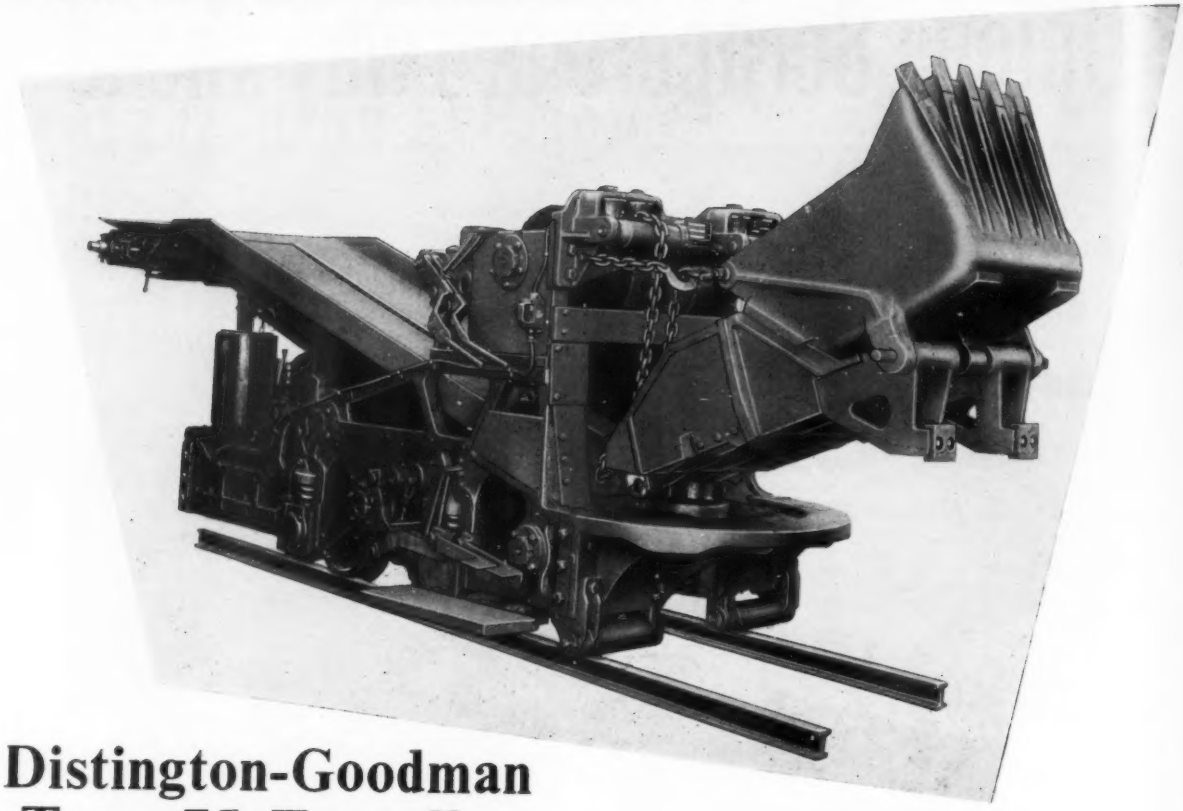

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The clean-up width of the Type 75 Tunneller ranges from 13 feet to 20 feet 9 inches according to the length of boom fitted.

This type of machine can be built for track gauges as narrow as 24 inches or as wide as 42 inches although the gauge may determine the maximum length of boom that can be fitted. Dual gauge machines have been designed to use a narrow gauge track for locomotion, and a wider track to give greater stability to the machine during loading operations.

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LOADING CYCLES PER MIN.		6
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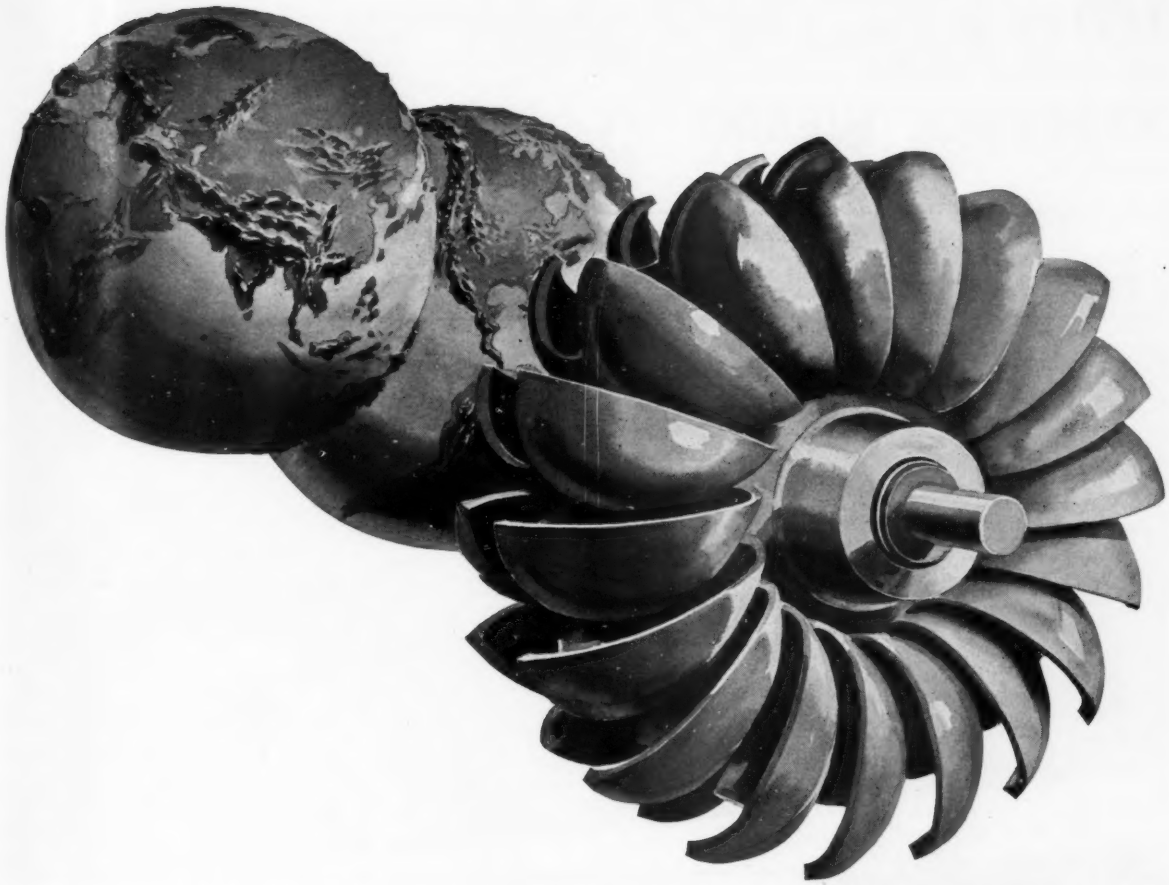

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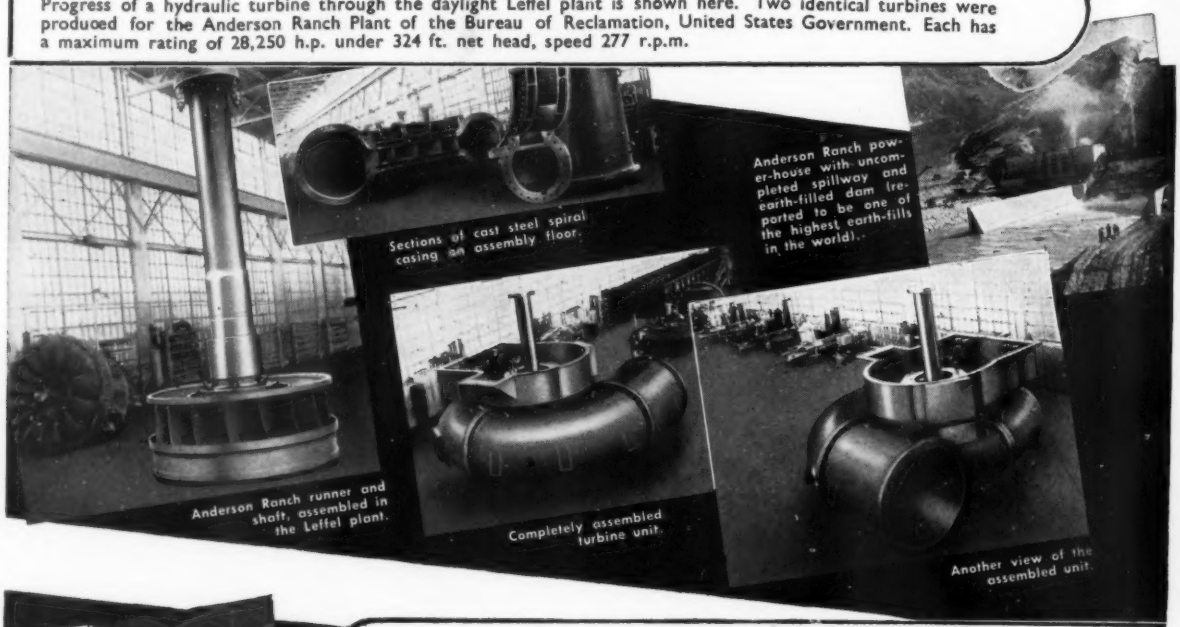
Progress of a hydraulic turbine through the daylight Leffel plant is shown here. Two identical turbines were produced for the Anderson Ranch Plant of the Bureau of Reclamation, United States Government. Each has a maximum rating of 28,250 h.p. under 324 ft. net head, speed 277 r.p.m.



Sections of cast steel spiral casing on assembly floor.

Anderson Ranch power-house with uncompleted spillway and earth-filled dam (reported to be one of the highest earth-fills in the world).

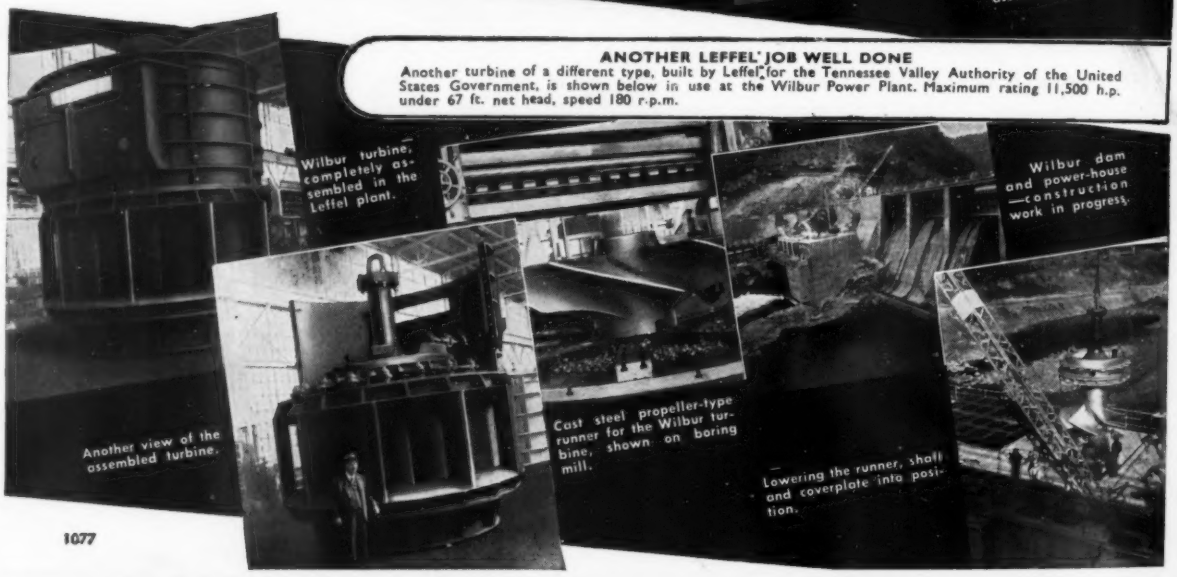
Anderson Ranch runner and shaft, assembled in the Leffel plant.

Completely assembled turbine unit.

Another view of the assembled unit.

ANOTHER LEFFEL JOB WELL DONE

Another turbine of a different type, built by Leffel for the Tennessee Valley Authority of the United States Government, is shown below in use at the Wilbur Power Plant. Maximum rating 11,500 h.p. under 67 ft. net head, speed 180 r.p.m.



Wilbur turbine, completely assembled in the Leffel plant.

Wilbur dam and power-house—construction work in progress.

Another view of the assembled turbine.

Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.

Lowering the runner, shaft and coverplate into position.

1077

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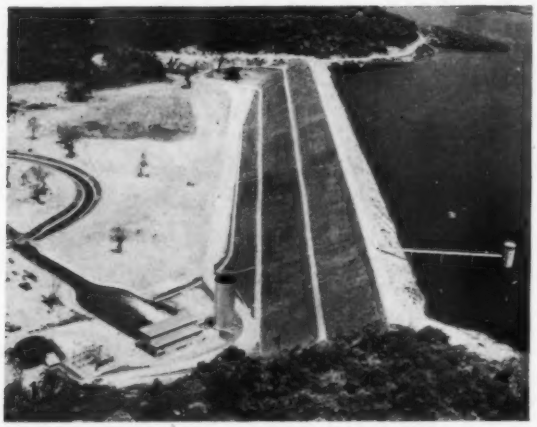

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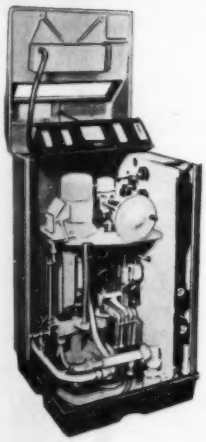

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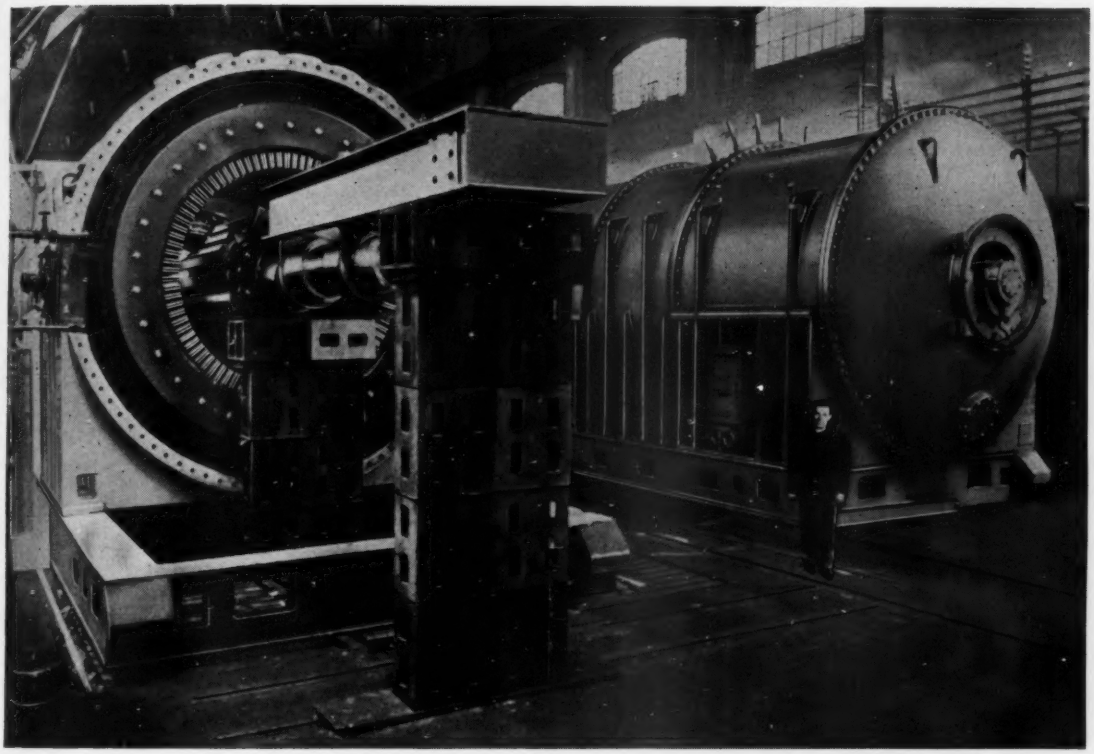

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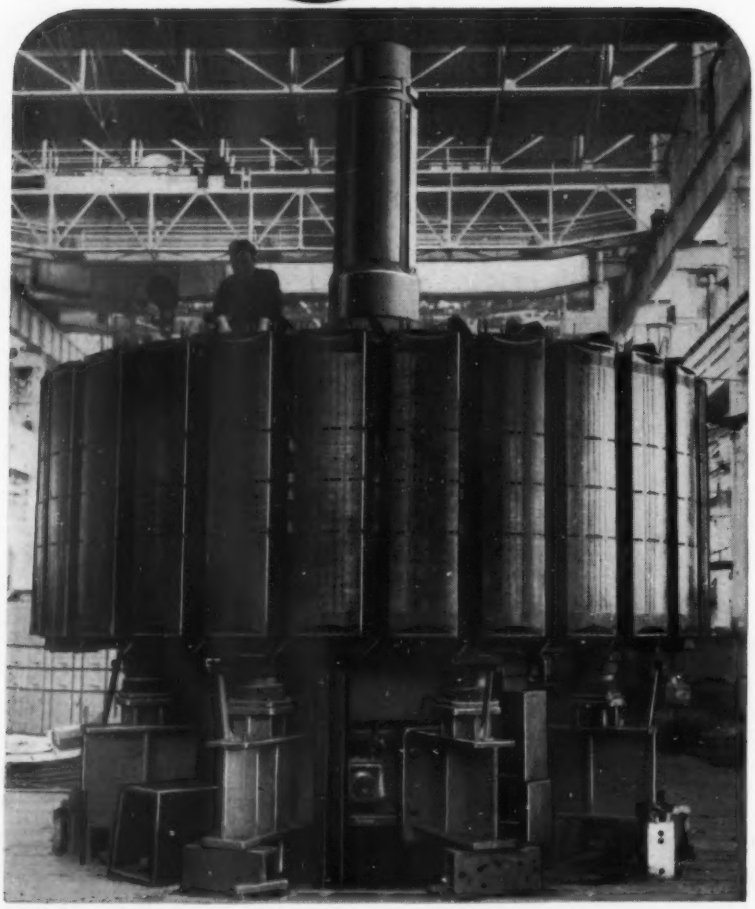

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Top: Artist's impression of the Los Peares Power Station, North-west Spain.

Left: Rotor (under construction, in the BTH works) for one of the three vertical waterwheel-driven alternators (62,400 kVA., 11,000 volts, 3-phase, 50 cycles, 214 r.p.m.) to be installed in the above Power Station.

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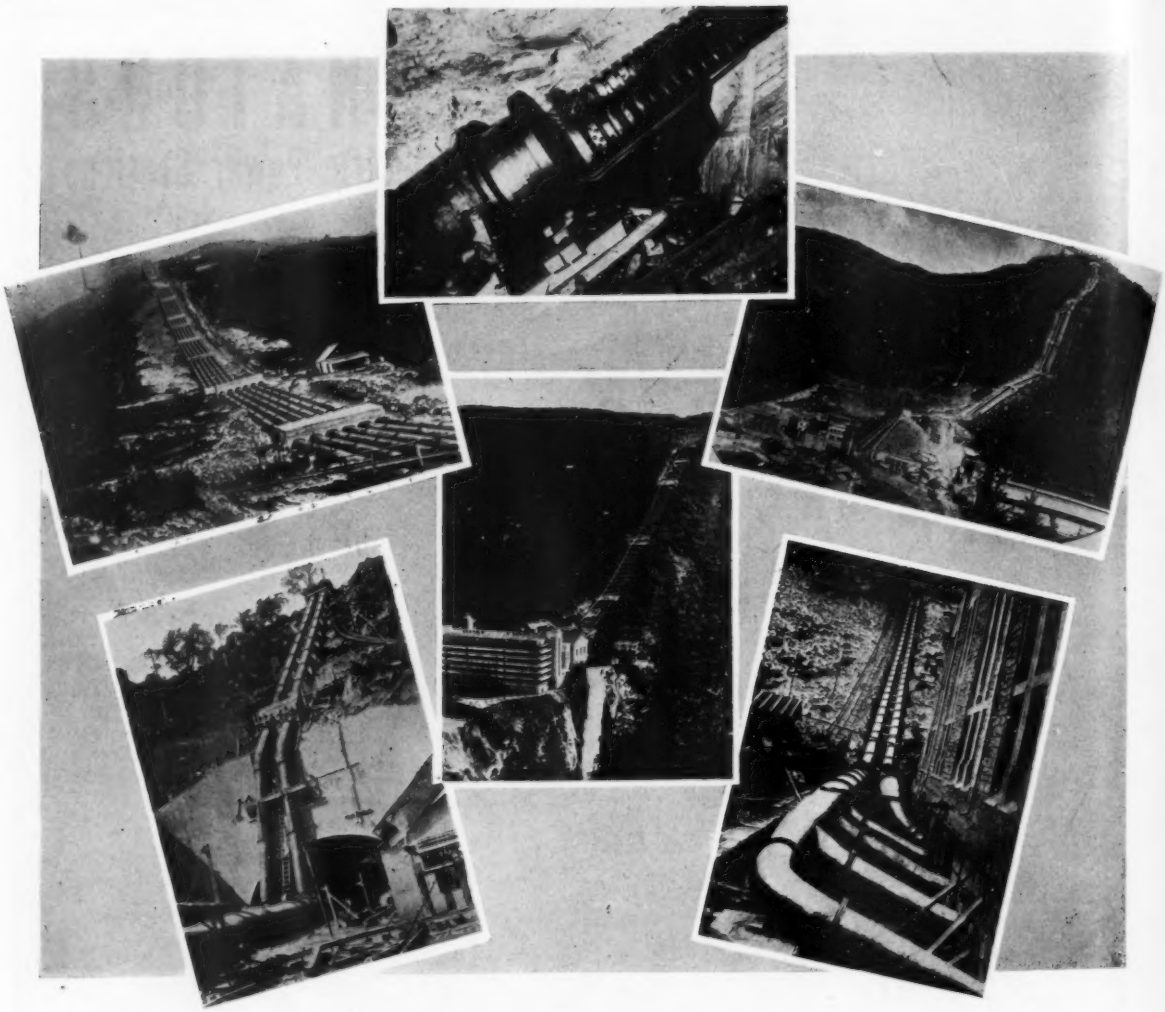

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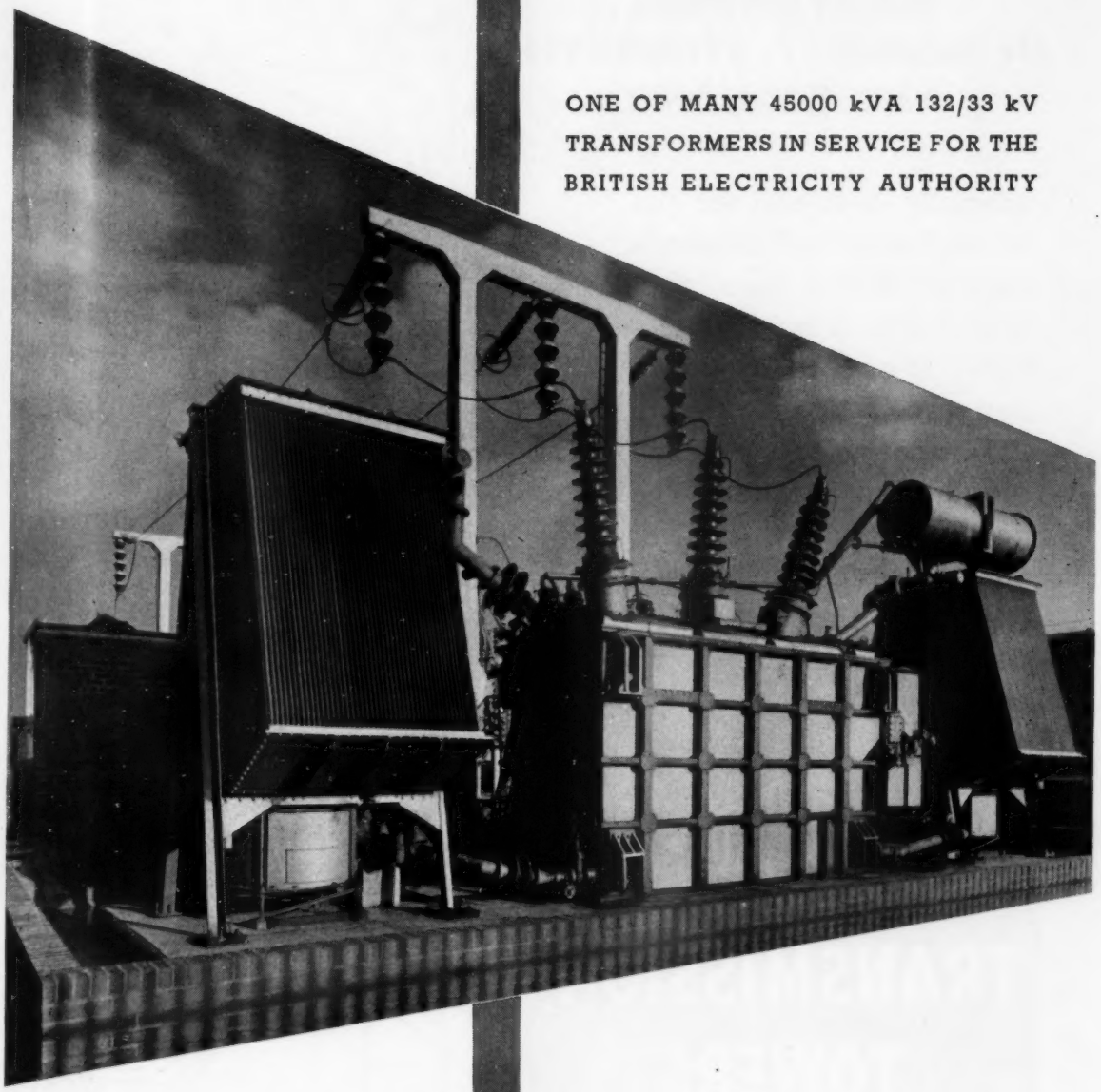

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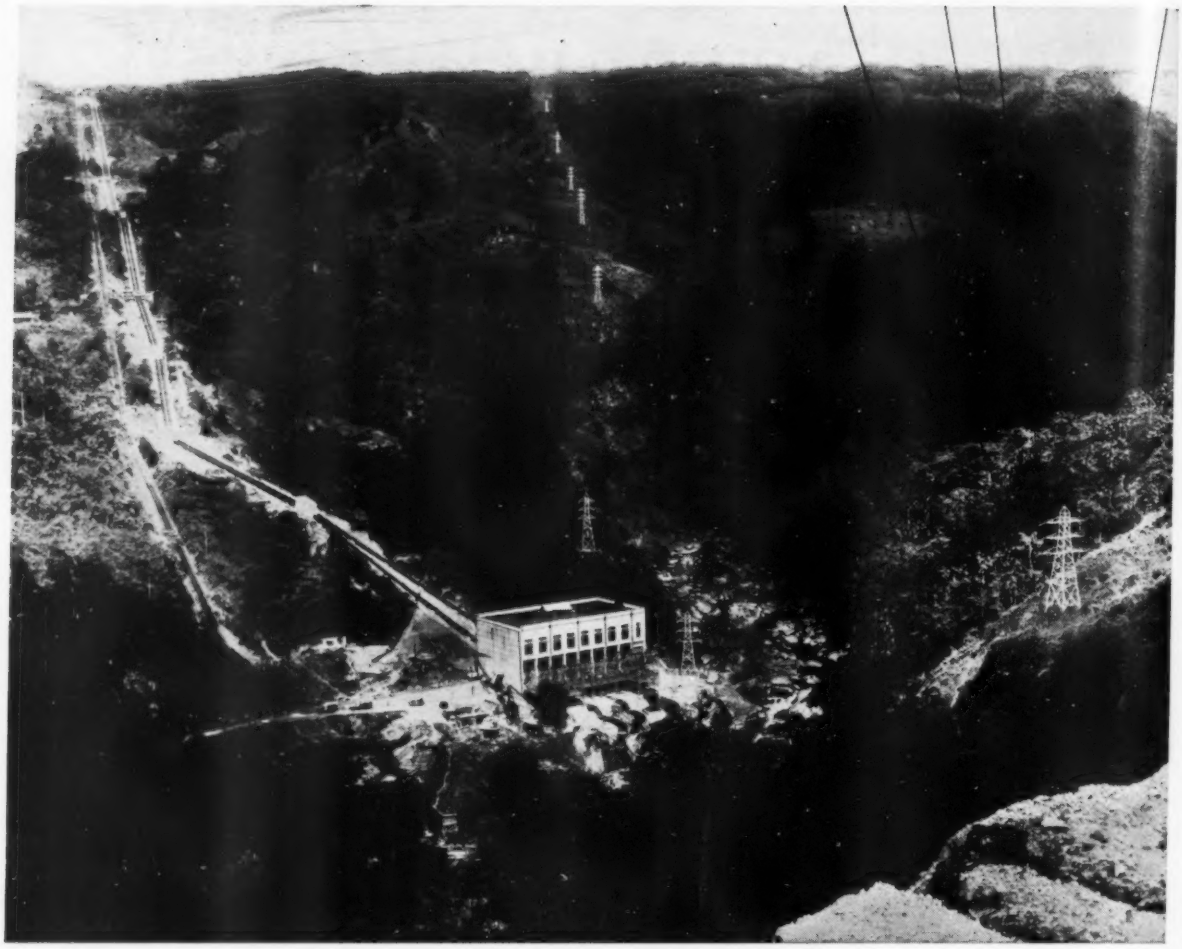

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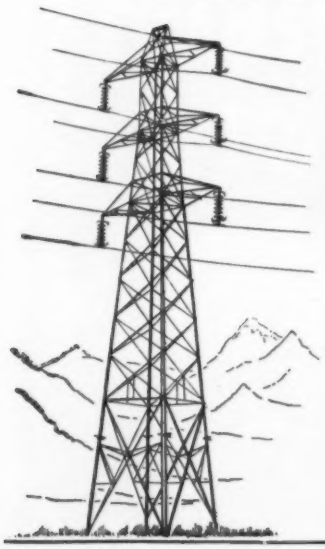

BICC OVERHEAD TRANSMISSION

It's a tough job erecting lines and towers across the mountains, valleys and jungles of Ceylon. But BICC Engineers are used to work of this nature : they have recently completed the overhead transmission system for the first stage of the Laksapana Hydro-Electric Scheme. This comprises seventy-eight miles of double-circuit 66kV line to carry 25,000 kW of power to Colombo and Peradeniya.

Survey, siting, supply and erection of this transmission system were all carried out by the BICC group—who undertake similar installations anywhere in the World.

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Statistics

THE United Nations agency known as the Economic Commission for Europe is a tireless compiler of statistics and Reports; and many of them relate to the hydro-electric field. The latest Report (E/ECE/EP/131) deals with "Hydro-electric Potential in Europe and its Gross, Technical, and Economic Limits." *

Before discussing the Report, it is as well to quote its basic definitions. "First there is a 'theoretical gross potential,' or the total water power theoretically exploitable. This idea is applicable to what might be called virgin country, i.e., to areas where the watercourses could be fully developed without regard for established interests such as towns built on sites suitable for the construction of reservoirs; crops, or thoroughfares, which cannot be moved; water supplies that must be reserved, etc. Thus the concept of theoretically exploitable resources represents an absolute maximum. There is of course also a 'technical potential,' which is at once more significant. In estimating it, account is taken of losses due, for example, to diversions or use of water for purposes such as irrigation. Lastly, potential may mean 'economic potential.' The assessment of economically developable resources is a much more difficult matter, as it depends both on the prevailing economic situation and on the relative meaning attached to the economics of a project by the services responsible for development planning."

In endeavouring to pursue the extremely useful ideal of assessing European hydro-electric potentials in a uniform manner on the three lines indicated above, the Secretariat deserve nothing but praise; but a house is no stronger than its foundations, and we must examine, in perusing this vast collection of statistics, the firmness of the foundations on which they are built.

In a very honest preface, the compilers say that almost every measurement needed for the assessment of hydro-electric potential, of any kind, is liable to grave inaccuracies. The national surveys—for example those published at the time of the World Power Conference, in 1950—are agreed to be inadequate and incompatible in respect of essential bases of comparison; and the published sources of reference, listed extensively at the end of the Report, can easily be shown to conflict in many vital aspects.

We are reminded, in reading the Report, of a certain steam power station of moderate size attached to a large factory, whose manager laid the greatest possible emphasis on exact costing and overall efficiency in production. The power-station superintendent, with no coal-weighing apparatus available, used to walk round the coal stack every morning, pace out the length and breadth, guess the height, and subtract his estimate of the coal on the ground from that which he had made the day before. He could, of course, measure the kilowatt-hour output of the station with great exactness; and he presented to the manager, each day, a thermal efficiency statement worked out to the fourth decimal place . . .

Of what value were his figures? It is true they formed a comparative guide as to whether, over a year, the station was more efficient or less efficient than in the previous twelve months, but even that assumption is perhaps giving them too high a value.

And so we come to examine this massive document. It is a model of statistical work: it is beautifully presented, and its earlier chapters, dealing with the physiographic basis of stream flow, and touching on methods of evaluation, are worthy of permanent retention (and might well be published in a more enduring form than the duplicated typewritten document we have before us). But the conclusions, we would suggest, can only be accepted in relation to the arguments set out above, concerning the extrapolation of statistics based on doubtful and conflicting premises.

With these reservations, then, we feel that the Report's conclusion may be accepted, that while the "theoretical gross potential" of the Central European hydro-electric regions is equivalent to an upper limit which can be fixed when mutually compatible methods of assessment have been decided, the "technical potential" has been rising steadily. This rise may be

*A factual review of this publication will be found on page 284

slowed down, as the cancelling-out of rising costs per kW (consequent on the harnessing of less attractive sites) by improvement in plant efficiency and by improvements in construction technique, tends no longer to apply. It is also suggested that the permissible costs per kW of hydro capacity will slowly be augmented, while technical horizons, in terms of exploitability of natural sites, will advance more slowly—in other words, limits to "technical" and "economic" potentials will tend to draw closer together.

We are glad to note that among the references quoted so profusely in the Report a high proportion emanates from the pages of WATER POWER; and we might perhaps be forgiven if we suggested that our regular readers may well have drawn—some time ago—the same conclusions as those reached in the course of nearly 200 pages of closely typewritten matter.

Bridge River Contracts

CONTRACTS totalling nearly $1,500,000 have been awarded to four British Columbia firms in connection with the B.C. Electric's new 62,000 h.p. hydro-electric unit at Bridge River. The general contract for the project went to Northern Construction Company and J. W. Stewart Ltd., whose bid of $887,000 was the lowest of five tenders invited. Fabrication of the 72 in. penstock that will drop the water 1,100 ft. down Mission Mountain to the power station on Seton Lake will be carried out by Vancouver Iron Works, Ltd., which bid $255,000 for the job. These big steel sections will be set in place and bolted together by Arrow Transfer Limited. Theirs was the lowest bid at $122,000. Steel for the penstock has been purchased from Dominion Bridge Company for $195,000.

Addition of the fourth generating unit at Bridge River, now under way, will make this station the most powerful source of energy in any utility system west of Ontario. It is now rated at 196,000 h.p., but will rise to 248,000 h.p. with the completion of the new machine early next summer.

A second major project in the Bridge River area, the 58,500 h.p. Seton Creek station, will get under way a little later this year. It is expected to cost $8,000,000, and is scheduled to send power to the Lower Mainland by the summer of 1955.

Winnipeg Electric Company's Staff Changes

THE acquisition by the Manitoba Hydro-Electric Board of the common shares of the Winnipeg Electric Company has had several results upon the structure and senior staff of the Winnipeg Electric Company. The activities of the company are now restricted exclusively to the electrical power business, and the Board staff has become integrated with the company into a single organisation to perform the functions of both. Then, too, it was the desire of a number of senior officers of the company, who had reached retirement age, to take retirement. The resulting staff changes are enumerated below.

Among those retiring are Mr. E. V. Caton, former Vice-President and Chief Engineer, and latterly Assistant General Manager and Chief Engineer. He, however, will continue in the capacity of Special Consultant to the management. Messrs. C. F. Lidster, former Comptroller and Treasurer of the Winnipeg Electric Company, S. N. Currie, former Secretary of the Winnipeg Electric Company, I. A. Mahon, former Sales and Merchandising Manager, have also retired. To this must be added the accession of Mr. D. M. Stephens as President and General Manager, succeeding Mr. W. H. Carter, who severed his connection with the Winnipeg Electric Company in February.

The new establishment, responsible to the new management, is as follows: Mr. L. M. Hovey, Manager of the System Engineering and Planning Division; Mr. A. S. Williams, assistant to Mr. Hovey; Mr. C. P. Haltalin, Manager of the Operating Division; Mr. J. R. Rettie, Manager of the Surveys and Construction Division; Mr. D. P. Martell, Comptroller and Treasurer; Mr. G. S. G. Henson, Manager of the Property and Supply Division; Mr. T. W. Birt, Manager of the Contract Department; Mr. A. L. Oddleifsson, Assistant to Mr. Haltalin in the Operating Division; Mr. H. C. G. Ligertwood, Assistant to Mr. Rettie in the Surveys and Construction Division; and Mr. D. S. G. Ross, Economic Studies and Cost Engineer.

Tignes Dam Inaugurated

THE Tignes dam, the highest in Europe, was officially inaugurated at the beginning of July by President Auriol, who afterwards visited the new village of Tignes which is being built to replace the old village now submerged. It will be remembered that the villagers appealed to the President to save their village, and Monsieur Auriol referred to their sacrifice in his speech at Malgovert power station. The Tignes dam is 180 m. high, has absorbed 650,000 cu. m. of concrete, and has created a reservoir of 235 million cu. m. usable capacity.

Moriston Scheme Amendment

IN order to economise in scarce materials an amendment has been made to the Moriston scheme by the North of Scotland Hydro-Electric Board and has been confirmed by the Secretary of State for Scotland. Power will now be developed in one stage instead of two, the water being taken from the reservoir at Dundreggan direct to a nearby underground station from which it will be discharged into a tunnel leading to Invermoriston. A subsidiary station which was to have been built near the Livishie dam will now be located near the Dundreggan dam. The amended capital cost is estimated at £13 million, but the estimated annual output of 213 million kWh remains unchanged.

Tungabhadra Dam in Commission

THE Tungabhadra dam, which forms the basis of a joint project undertaken by the State of Madras and Hyderabad and has been constructed entirely by the Indians, has just been brought into commission, flow from the reservoir having been commenced in July. It is a gravity masonry structure built of random granite rock, 3,642 ft. long and 160 ft. high above deepest foundation, and is designed so that the height can be increased by 5 ft. when desired. It impounds 2·6 million acre ft., which will be used mainly for

irrigation. Two canals are being constructed for this purpose, one 225 miles long in Madras and the other 127 miles long in Hyderabad. Power for Madras to the extent of 48 MW will be provided in two stations, and for Hyderabad 110 MW will be provided in five stations.

New Station in the Cameroons

DURING June, 1953, the first 10,000 kW unit in the Edea power station of L'Energie Electrique du Cameroun, was commissioned. This plant is situated on the river Sanaga, about 75 km. from Douala; and the first stage will comprise two 10,000 kW units operating under a 24 m. head and having a combined annual output estimated at 170 million kWh. It is hoped that within several weeks the second unit will also be commissioned.

The second stage will bring the total installed plant to three units, all of the same size, and the civil-engineering work for all three has been carried out under the initial plan. The final stage, now being planned, will bring the output of the station up to either 80 or 100 MW.

A 90 kV overhead line carries the energy from the station to the town of Douala.

New Dam in Sardinia

THE Cassa del Mezzogiorno (Fund for the South) has approved plans for a new dam across the Flumendosa River, in Sardinia. It is stated that the dam, which will cost an estimated 8,571 million lira (£4,857,750), will be the largest in Europe.

St. Lawrence Seaway Prospects

CANADIAN hopes of eventual American participation in the St. Lawrence development have been somewhat revived by the action of the Federal Power Commission's examiner, Glen R. Law, in ordering the issuance of the 50 year licence to New York State Power Authority to build the 940·5 MW station at the International Rapids. It is felt in Ottawa that a favourable F.P.C. decision in the American courts can be reasonably anticipated although delaying tactics on the part of the opponents are to be expected. It is hoped that the way may be clear for a joint American-Canadian undertaking at the Rapids by next spring.

Whether American participation is likely to extend to the Seaway is another matter. When Mr. St. Laurent was in Washington recently, President Eisenhower stated that he and his Cabinet fully supported the Seaway, but in view of the fact that the agreement of 1941 has not been ratified in spite of the support of both President Roosevelt and President Truman, the prospects are regarded with reserve.

Australian Electrical Exhibition

THE Electrical and Radio Federation (Victoria) of Australia is planning to hold a £1,000,000 Exposition in Melbourne in October 1954. It is to embrace exhibits from all over the world covering the latest in electrical appliances and equipment, radio, radar, television and telecommunications, and will demonstrate the contributions made to advancement by Australian manufacturers and electrical engineers.

The generation of power and the associated activity of water conservation and distribution will also be an outstanding feature of the Exhibition, and it is expected that the State Electricity Commission of Victoria and the Snowy Mountains Hydro-Electric Authority will be able to present the public with a panoramic view of what has been done, what is now being implemented, and what the future plans will be.

Volta River Progress

IN opening the new session of the Gold Coast Assembly, the Prime Minister, Dr. Nkrumah, announced that the Government proposed to establish a national committee for the Volta River project, consisting of the Minister of Finance, the Minister of Commerce and Industry, and three nominees from the Assembly. This committee would make recommendations to the Government in order to safeguard the interests of the Gold Coast and would work in close touch with the Special Commissioner. It was intended to call in consultants of international reputation to advise on the engineering, economic and financial aspects of the scheme, and Dr. Arthur Morgan, first chairman of the Tennessee Valley Authority, and Professor Arthur Lewis, of Manchester University, have already accepted invitations in this capacity.

South Saskatchewan River Project

THE Saskatchewan Government has offered to pay 20 million dollars towards the construction of the main dam in the proposed South Saskatchewan River irrigation and power project and has asked the Federal Government to decide whether the offer is satisfactory. The province estimates the total cost at 130 million dollars.

Gaur Station Official Opening

ON June 20 the Right Hon. Robert Gordon Menzies, Prime Minister of Australia, opened the North of Scotland Hydro-Electric Board's new Gaur hydro-electric station at Rannoch, Perthshire, in the ancient lands of the Clan Menzies. Mr. Menzies, who was accompanied by his wife and daughter, was presented with two token young Scots pines taken from the Black Wood of Rannoch. Later on, at a more suitable planting time, the young trees packed in their native soil will be flown to Australia.

The Gaur hydro-electric scheme, which will produce about 17,000,000 units of electricity annually, is situated on the edge of the Moor of Rannoch 13 miles west of Kinloch Rannoch. There is a 50 ft. dam at the outlet of Loch Eigheach and a 6,000 kW power station on the River Gaur which flows into Loch Rannoch near the Black Wood of Rannoch, one of the few surviving and reseeding parts of the old Caledonian Forest. The power station will be faced with Rannoch granite. Beside the scheme is a finger post indicating the old road to the Isles.

The station contains a single English Electric set comprising an 8,400 b.h.p. vertical Francis turbine running at 214 r.p.m. under a net head of 86·5 ft. and driving an umbrella-type 11 kV alternator. Power is transmitted by an existing 33 kV line to Rannoch power station where it is stepped up to 132 kV.

Book Reviews

Hydro-Electric Potential in Europe, and its Gross, Technical and Economic Limits United Nations Economic Commission for Europe, Committee on Electric Power. 200 pp., 13 charts and maps, 31 tt. Mimeographed production in paper covers. English edition; French edition in course of preparation. Obtainable from Sales Section, European Office of the United Nations, Palais des Nations, Geneva, Switzerland. Price 7s. 6d. sterling, $1, 4 Sw. fr.

As is rightly stated in a preliminary note, the main value of this study lies in its attempt to establish a uniform approach to the problem of assessing hydro-electric potential. Three levels of potentiality are envisaged—theoretical, technical, and economic—and it is shown that a relationship tends to be revealed between these levels which is of assistance in assessing practical limits to development in different regions.

The definition and assessment of these levels are discussed in detail in the third chapter, which is preceded by a chapter on the physiographic basis of stream flow, and this in turn by a chapter on factors affecting hydro-electric potential, such as hydro-thermal cost ratio, and technical and economic influences. In chapter four a detailed analysis is made of gross hydro-electric potential in Continental Europe, and in chapter five the conclusions are summarised.

The gross potential for Continental Europe is given as 1,278 milliard kWh, and the aggregate economic potential as derived from official statistics is 244 milliard kWh, or 19 per cent. of the gross. As a result of this study it is thought that the figure for economic potential could be increased by about 50 milliard kWh, or 20 per cent. For the whole of Europe, apart from Iceland and the U.S.S.R., a total yearly production of 514 milliard kWh per annum is at present accepted as economically possible. Of this, about 22 per cent. had been developed by 1950 and about 26 per cent. by December, 1952.

The importance of investigations of this kind is believed to lie in the establishment of upper limits which facilitate investment planning, and the conception of gross potential is important in enabling a preliminary assessment to be made of the potentialities of less-developed countries. In no European country where significant hydro-electric production is possible has more than one half of the possible output yet been developed, and the study tends to justify continued reliance on hydro production in countries where it is already of importance.

In this review we have confined ourselves to a brief summary of the main theme of the study, and have reserved comment to our leader on page 281.

Manual on Rock Blasting. Editor-in-Chief, K. H. Fraenkel. Published by Aktiebolaget Atlas Diesel, Stockholm, and Sandvickens Jernverks Aktiebolag, Sandvickens. Obtainable from any member of the Atlas Diesel organisation throughout the world. Price in Great Britain, £5 5s. post free for home or overseas, from The Atlas Diesel Co. Ltd., Beresford Avenue, Wembley, Middlesex.

A small handbook on the technique of rock blasting was published in Sweden in 1944, but when the International Congress on the Driving of Tunnels in Rock was held in Paris in 1949 it became evident that the time was ripe for an international exchange of information on the subject.

The present book is a definite attempt to meet that need, and it is, perhaps, appropriate that it has been sponsored by those who have pioneered what is universally referred to as the Swedish method of drilling. Nevertheless there is little attempt to make company capital or to produce a firm's catalogue, as the book is purely technical and is planned as an international textbook for civil and mining engineers.

About 20 papers have been contributed by 14 authors, the contents being arranged under the headings: Geology; Terminology; Rock Blasting Methods; Planning and Practical Results; Compressed Air Supply; Drill Steels; Explosives, Charging, Firing; and Ventilation. Most of the contributors are Swedish and all are European, but the resulting obvious omissions are to be remedied by the inclusion of further material from other sources as opportunity arises, and to this end the book is presented in loose-leaf form so that these additions can be inserted in their appropriate sequence. A list of 11 supplementary articles to be added shortly is, in fact, cited.

The value of the book to an international readership is enhanced by the fact that it is presented throughout in four languages—English, French, German and Swedish—which appear in four columns on each opening. Strangely enough for a book dealing with the rough realities of rock blasting there is no bad language—not even in the glossary of technical terms! Indeed, although we cannot speak with authority as to the Continental languages, we find the English version beyond reproach.

Hydraulics Research Meeting

A joint meeting of the International Association for Hydraulic Research and the Hydraulics Division of the American Society of Civil Engineers will be held at Minneapolis at the University of Minnesota on September 1—4, 1953. Over 50 papers will be presented under the following classification: Basic Relationship of Sediment Transportation by Flowing Water; Density Currents; Air Entrainment by Flowing Water; and Waves, Beach Erosion, and Hydromechanics of Shore Structures. Further information concerning the conference can be obtained from Professor Loyal A. Johnson, St. Anthony Falls Hydraulic Laboratory, Minneapolis 14, Minnesota, U.S.A., and enquiries for membership in the International Association for Hydraulic Research should be sent to Dr. Lorenz G. Straub at the same address.

Aluminium Wire & Cable Co. Ltd. On and after August 15 the address of the sales office of this company will be changed from Thurloe Street, London, S.W.7, to 30, Charles II Street, St. James's Square, London, S.W.1. Telephones, Trafalgar 6441/6; telegrams, Aluminwire, Piccy, London.

Portable Air Compressors. Holman Brothers Limited, Camborne, Cornwall, have published an excellent catalogue describing their portable air-compressor sets. The special features of their two-stage compressor units are explained and illustrated in detail, and numerous photographs show these machines in service in every imaginable situation.

Cross-Channel Power Project

Experiments with Underwater Cables

AN intermediate stage has now been reached in the project to link the power resources of the British and French electricity systems by an underwater cable. A joint committee of the British Electricity Authority and Electricité de France, which was set up in 1949 to study the practicability of effecting such an interconnection and the economic case for it, has already agreed that there is a *prima facie* case for a cross-channel power cable; but it recommended a detailed technical examination of the problems, involving a considerable expenditure, before a final decision was reached. To that end a series of submarine cable-laying trials are being carried out this summer off the south coast near Dover. It is expected that a whole series of tests will be completed early next year, and coupled with parallel investigations of certain other problems will prepare the way for the submission of a report on the main project.

This month the Post Office cable-laying ship *Alert* will lay two half-mile lengths of cable of British manufacture, and these will be jointed at sea to a 300 yard length of cable provided by French manufacturers. After certain electrical tests the cables and joints will be recovered and returned to the works for tests to demonstrate whether and to what extent they were damaged during the laying operations. In France a programme is being developed for a sea trial of two to four sections of gas compression cable, the sections being about 100 yards long. The cables will be laid off a jetty in deep water and joined to form a loop. Tests will include loading cycles and direct-current tests. Investigations will then be undertaken to study the practicability and sensitivity of different methods of locating a gas fault, made artificially at a known point. It may also be possible to test the maintenance of gas pressure and of penetration of sea water into the insulation under fault conditions. The cost of the work is being shared equally between the two authorities.

Two types of cable are to be investigated — the external gas compression cable and the pre-impregnated gas pressure cable; the former because of its high inherent electric strength and the apparent extra security against damage provided by the two lead sheaths, and the latter because of its simplicity and the possibility of manufacture in long sections.

In Britain attention has been mainly concentrated on the pre-impregnated gas pressure cable, and in particular on the manufacture of sample lengths of suitable armoured cable, of flexible joints with a diameter not exceeding that of the cable proper, and of rigid joints suitable for expeditious repair at sea. These components will be subjected to rigorous mechanical and electrical type tests at the works. In France similar work is being undertaken on two designs of external compression cable and two designs of pre-impregnated pressure cable. In addition, Electricité de France will carry out at the Fontenay Research Centre severe mechanical and electrical tests on lengths of both types of cable and on joints. Samples of each type of cable, about 125 yards long, will be subjected, while connected-direct to the French 225 kV system, to long duration stability tests under artificial loading cycles.

Frequency control will have an important bearing on the security of operation of the interconnected national systems, and its effect will be assessed from tests on the two systems. Day-to-day operational information is now being exchanged between Electricité de France and the B.E.A. in order to study the potential economic exchanges of power and the savings in operational costs which might be effected.

The main project, as envisaged by the joint committee, comprises a 132 kV cable circuit, laid approximately between Dover and Calais, and connected into the British 132 kV system on one side and the French 90 kV and 225 kV systems on the other. The cable circuit would be made up of three single-core cables, with possibly a fourth as spare. There is at present no installation in the world comparable to the cross-channel cable, which will be about 26 miles in length, although in Canada a scheme has been adopted for crossing the St. Lawrence River with 69 kV cables, having a capacity of about 75,000 kW and a length of about 30 miles.

Institution of Civil Engineers Conversazione

At the annual conversazione held recently at the Institution of Civil Engineers there was an admirable display of models and scientific apparatus showing recent achievements and developments in civil engineering. Perhaps the exhibit of most direct interest to hydro-electric engineers was that presented by Mr. C. M. Roberts, M.I.C.E., this being a model showing the method used in heightening the Mullardoch dam, as described in our May 1952 issue. Adjacent was a diorama, presented by Sir William Halcrow, M.I.C.E., of the Claerwen dam, the highest in Great Britain, constructed for the City of Birmingham Water Department. This dam is 222 ft. high from foundation to spillway, 1,166 ft. long, and 180 ft. thick at the base.

A working model exhibited by Mr. H. Q. Golder, D.Eng., A.M.I.C.E., showed the effect of an apron and cut-off in reducing leakage through a pervious sand spur into which it was proposed to build a dam, as well as examples of the use of deep-well dewatering in excavating pervious ground.

Several exhibits were presented by the Department of Scientific and Industrial Research. The Hydraulics Research Station showed a wave-height analyser and also miniature current meters for measuring water velocities in models of harbours and river estuaries. The Building Research Station showed examples of electrical, mechanical and hydraulic load gauges for use in field and laboratory, and the Road Research Laboratory demonstrated the action of snow fences by means of a wind tunnel.

The exhibit presented by George Wimpey & Co. Ltd. included wellpoints with specially shaped washers instead of gauze, the use of "no-fines" concrete for building construction, and a lifting tongs for handling large blocks of rock.

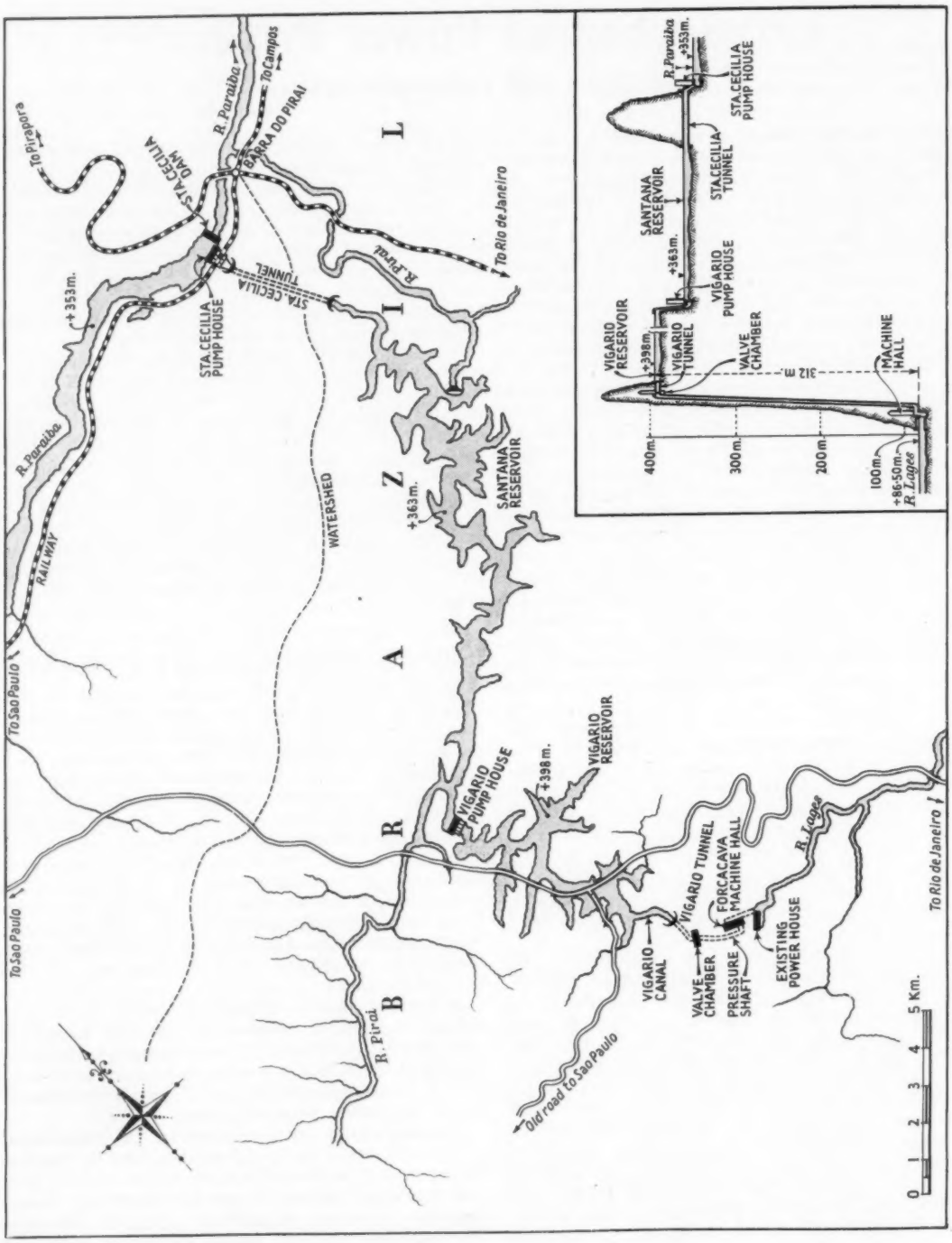


Fig. 1. Map and profile diagram of the Paraiba-Pirai diversion

THE PARAIBA-PIRAI DIVERSION

Fig. 2. General view of the Santa Cecília dam and pump house

The Paraíba-Piraí Diversion

In this important Brazilian diversion scheme, the first stage of which was inaugurated last year, 5,650 cusecs are being diverted from the Paraíba River, conveyed nearly 20 miles and raised 148 ft., to take advantage of a head of 1,130 ft. in the Lajes valley. The additional capacity should meet the needs of the Rio system until at least 1960.

BRAZILIAN TRACTION, LIGHT & POWER CO. LTD., Toronto, the largest Canadian company operating exclusively outside Canada, originated upwards of 50 years ago as a small public utility company, the São Paulo Tramway, Light & Power Company, formed to operate the city's tramways by electricity. The first hydro-electric plant, consisting of two 1,000 kW generators, was installed in 1901, and in 1912 a hydro plant was constructed at Soracaba. The culminating engineering feat in the São Paulo area was the Serra do Cubatão diversion, in which a storage area of 49 sq. miles was laid under water and a head of 2,296 ft. obtained by diversion over the escarpment. This scheme was engineered by the late Dr. A. W. K. Billings, who also projected the development which forms the subject of this article.

In the Rio de Janeiro area, with which this article is concerned, the Rio de Janeiro Tramway, Light and Power Company was formed in 1904, and its first plant, at Fontes, was built in 1908 to utilise the waters of the Lajes River.

The topography of south-eastern Brazil is somewhat unusual. A plateau, the Serra do Mar, runs parallel to the Atlantic coast for nearly 1,300 miles, ranging in height from 1,000 to 2,500 ft., and tilts slightly away from the coast. Consequently most of the streams flow inland and form large rivers which discharge to the north or south of the plateau. The Lajes River is one of the few exceptions in that it discharges to the seaward side of the escarpment by a series of waterfalls.

A gravity dam, 105 ft. high, was built across the river above the falls, forming a storage of 147,530 acre ft. at a level of 1,260 ft. above sea level. Thence a system of two feeders of 8 ft. diameter, partly in tunnels, led to six steel penstocks serving six 4,000 kW vertical-shaft Pelton-wheel sets with an overload rating of 6,000 kW operating under a head of 1,016 ft. at the Fontes station.

After only five years, however, the need for additional plant was felt, and in 1913 a dam was built on the Piraí River at Tócos and the water diverted by gravity flow through a five-mile tunnel extending through the divide to the Lajes reservoir. This permitted the installation of two larger Pelton-wheel sets, increasing the capacity of the Fontes plant to 63,000 kW.

This development was of fundamental importance,

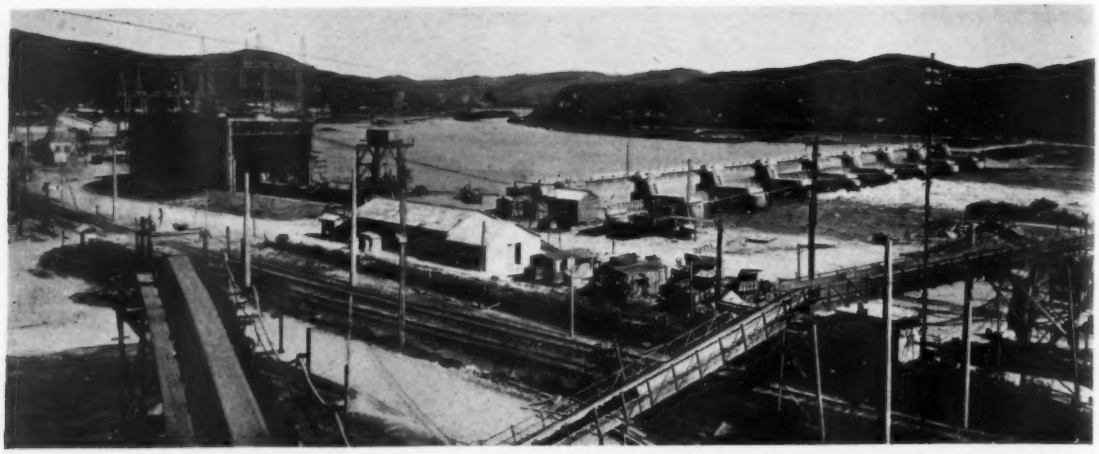


Fig. 3. Downstream view of the Santa Cecilia dam with the pump house under construction

for it established the principle of diverting inland-flowing rivers, with their large flows, to take advantage of the high heads available from the escarpment to the sea.

After the first World War further expansion became necessary, and a new generating plant, commissioned in 1922, was built at Ilha dos Pombos on the lower reaches of the Paraíba River. It is a run-of-river plant operating under a head of 105 ft., and originally consisted of two 22,000 kW units, but units of 29,000, 44,000 and 45,000 kW were installed in 1929, 1937 and 1949 respectively.

By operating the Ilha dos Pombos and the Fontes plants in conjunction it has been possible to ensure a regular supply of electricity at all seasons. During the rainy season the Ilha plant operates almost continuously at full output, which enables water to be accumulated in the Lajes reservoir so that the Fontes plant can supply the bulk of the power during the dry season.

By the late 1930's it became evident that further capacity would be needed at the Fontes station, and a new 35,000 kW unit was ordered in 1938 and set to work in 1940. This in turn intensified the problem of providing sufficient water reserve for the Fontes plant, for the demand was now such that the advent of drought years would have created a critical situation. An entirely new plant near Rio de Janeiro appeared to be the best solution, but this was ruled out by the prevailing war conditions. Accordingly it was decided to raise the height of the Lajes dam in stages by 92 ft., increasing the storage capacity from 147,530 to 852,757 acre ft. Two feed tunnels were also to be constructed between the face of the dam and the existing valve house.

The original dam was a mass concrete gravity structure, arched in plan, and it was heightened by building a series of radial buttresses against the downstream face. Piers were built on the top of the dam in line with the buttresses, which were mated to them by

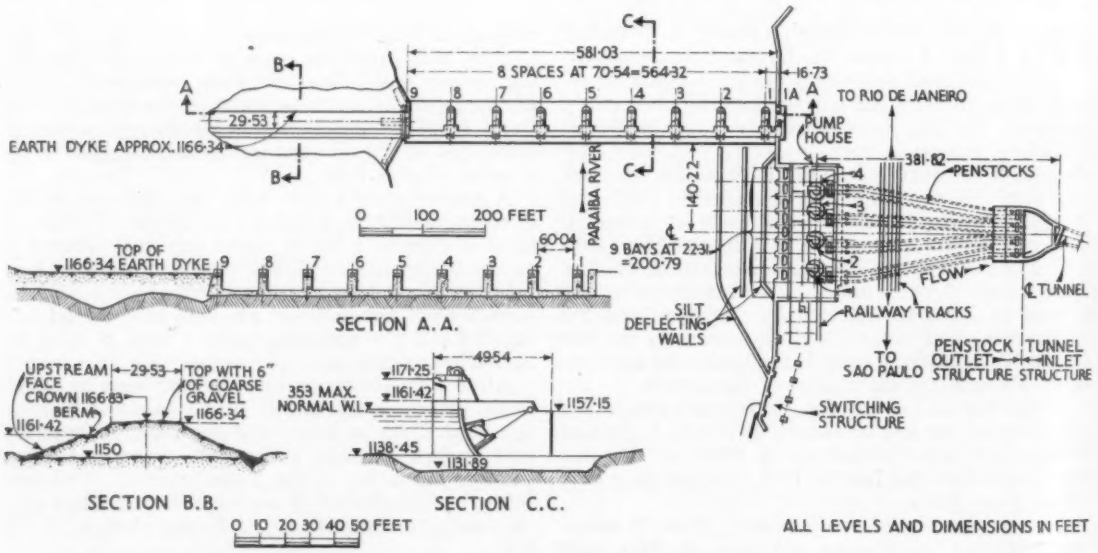


Fig. 4. General arrangement of Santa Cecília dam, pump house, penstocks, and tunnel inlet structure

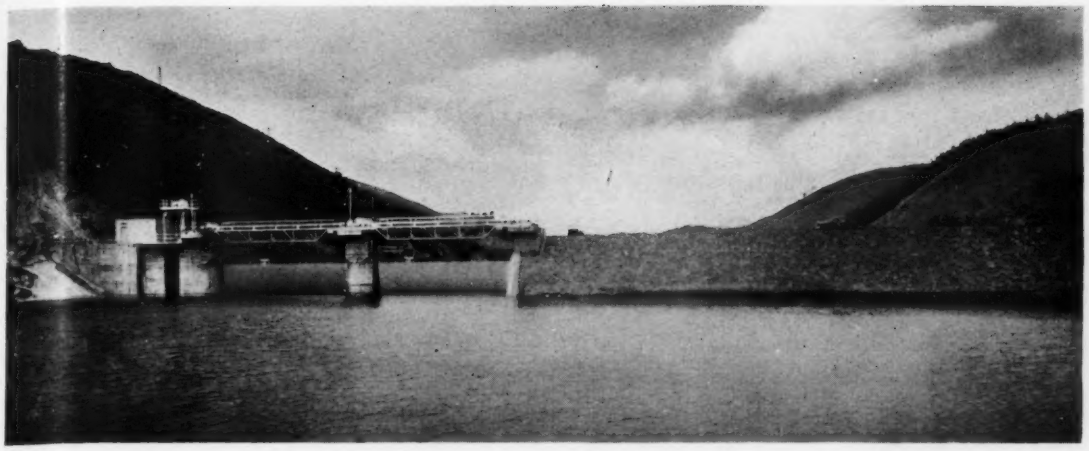


Fig. 5. Santana dam seen from upstream

toothed faces, and curtain walls built between adjacent piers. Where the piers rested on the downstream face of the dam the old concrete was notched and steel dowels grouted in.

This work was commenced in 1941 and continued until 1948, by which time one of the feed tunnels had been constructed and the dam had been raised by 63 ft. The additional capacity was then deemed to be sufficient for existing requirements, and further work was deferred in favour of the Paraíba-Piraí diversion.

Concurrently with the raising of the dam a second 35,000 kW unit was installed at Fontes in 1942 and a third in 1947. These three sets are of the Francis type, and when installed were among the highest-head turbines of this type.

The Paraíba-Piraí Diversion

Before the developments just outlined were completed, it became evident that even the anticipated additional generating capacity and water reserve would be insufficient to cope with the rapid increase in the demand, which was growing at a rate of 9 per cent. per annum. The success of the earlier Serra do Cubatão diversion led to the formulation of a basically similar scheme to divert waters of the Paraíba and the Piraí to the valley of the Lajes.

This scheme (see Fig. 1) is designed to divert up to 5,650 cusecs from the Paraíba River and to convey it a distance of about 20 miles to a point where it can be used by the Fontes power station and also by Forçacava, an underground plant being constructed in the mountainside adjacent to Fontes. The diversion point is at Santa Cecília, 2 km. upstream of Barra do Piraí, 100 miles above Ilha dos Pombos, where a basin known as the Santa Cecília reservoir has been formed by damming the river. Two pumping stages are required to raise the water 148 ft. to the valve chamber at Fontes, the first stage being located at the Paraíba offtake and delivering through a tunnel and an open canal to a second basin—the Santana reservoir—formed by a dam across the Piraí and receiving the flow of the Piraí River below Tocos. From this basin the second, and main, pumping stage raises the water to a reservoir formed in the valley of a smaller stream — the Vigario — whence it flows through a canal and tunnel to the valve chamber.

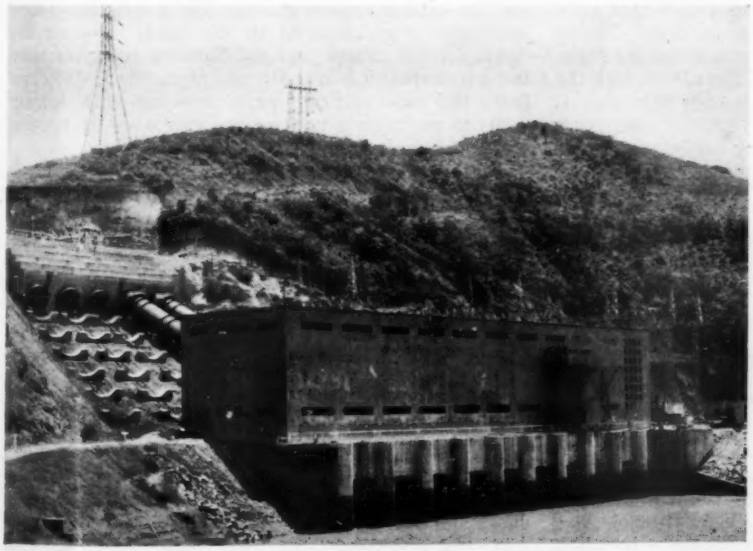


Fig. 6. Vigario pump house showing the penstocks for the present two units in position

This development will somewhat reduce the output from Ilha dos Pombos, but the diverted water will generate several times the energy at Forçacava that it could at Ilha dos Pombos.

Views of the works at Santa Cecília appear in Figs. 2 and 3, and a general arrangement drawing in Fig. 4. The

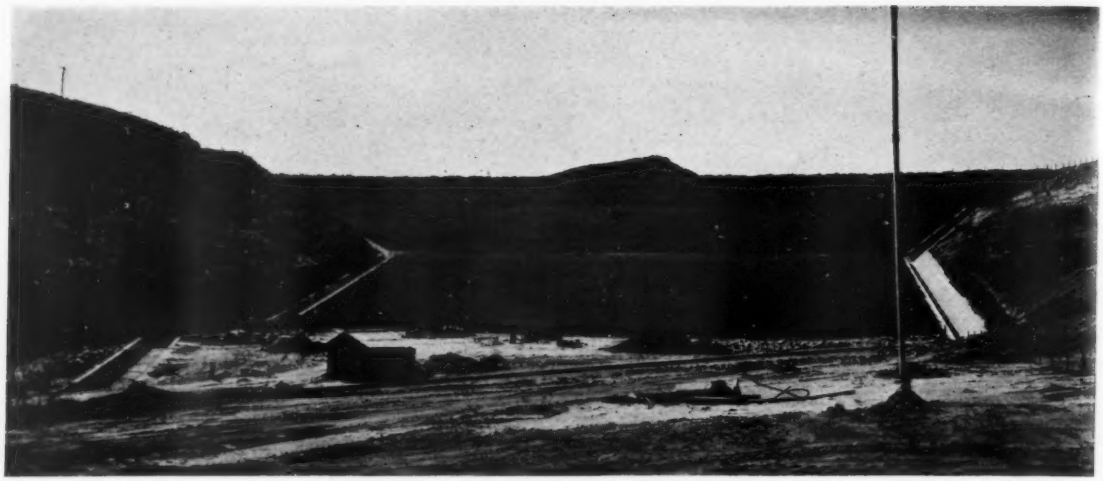


Fig. 7. The Vigario earthfill dam seen from the downstream side

dam is 853 ft. long and consists of a concrete spillway section the left-hand end of which is closed by an earth embankment 279 ft. long. The spillway section consists of a base slab and heavy piers to take nine tainter gates, eight being 20 ft. high by 60 ft. long to control the main flow, and the ninth, 10 ft. 6 in. long, to pass compensation water. The normal spillway capacity is 130,000 cusecs, which is substantially above the maximum recorded flood, and, in fact, the open gate area is larger than the original channel cross section, so that the dam will not produce any backwater effect during floods.

The Paraíba River contains a high proportion of sand and silt, and one of the main problems was to prevent this abrasive material from entering the pumps. To ensure that the main bed load is passed downstream, the sill of the dam has been placed below the level of the normal river bed, and the pump station has been protected by silt-deflecting walls which have been designed on the basis of model tests. During floods, when most or all of the tainter gates are open, the outer silt wall deflects most of the silt through the gates, and any that finds its way over this wall is sluiced out by the eddies formed between the outer and intermediate walls. During dry periods the space between the walls acts as a settling chamber, and the deposit is readily sluiced out by a slight opening of the end gates.

Each tainter gate is provided with its own motor, but any motor can be coupled to the adjacent gate so that it can take over in the event of a motor breaking down.

In the adjacent Santa Cecília pumping station a total of four vertical-shaft pumps will be installed, each capable of delivering 1,400 cusecs against a static head of 33 ft. and driven by a 9,500 h.p. synchronous motor. Each pump delivers through a 13 ft. butterfly valve to a reinforced-concrete penstock 13 ft. in diameter by 279 ft. long, the four penstocks passing under a railway track and terminating in an outlet structure which forms the entry to Santa Cecília tunnel. Two pumps are now in service, the third is being installed, and the fourth is planned for installation in 1954.

This station operates more or less continuously, but should any unit not be required for pumping it can be run as a synchronous condenser. To reduce the starting load on the synchronous motor and for operation as a synchronous condenser, the pump casing is dewatered by closing the butterfly valve and injecting compressed air into the pump casing, the unit then being brought up to speed. For pumping service the air is then gradually released, and after the full discharge water pressure has built up the butterfly valve is opened to establish the discharge.

The Santa Cecília tunnel pierces the range of hills separating the Paraíba and Piraí valleys and is just over two miles long. It is of horseshoe section, 436 sq. ft. in cross-sectional area, and is concrete lined throughout. It is of the free-flowing type and discharges into a canal section, 8,200 ft. long, leading to the Santana reservoir. The canal is in three approximately equal sections, the first and third being in earth and the central section in rock. Three large transition structures were required in the canal between the Santa Cecília tunnel and the Santana reservoir, and the two expansion transitions—from the tunnel and from the rock section—were provided with splitter walls to maintain a uniform velocity over the section and to minimise scour.

Santana dam is 36 ft. high and 360 ft. long, of which 198 ft. consists of earth embankment. The spillway section consists of two tainter gates identical to those at Santa Cecília, and a small broome gate. The Santana reservoir has a capacity of 18,000 acre ft. and covers an area of about 10 sq. miles, at a water level of 1,191 ft., stretching from the village of Santanésia to the town of Piraí.

From the Santana reservoir the water receives its main lift of 115 ft. to the Vigario reservoir through the Vigario pumping station. The pumping units have the same individual capacity as those in the Santa Cecília station—1,400 cusecs—and have similar mechanical and hydraulic features, but because of the much greater lift required the pump impellers are of large diameter and the motors are each rated at 22,500 h.p. The discharge from each pump passes through an 11 ft. 6 in. butterfly valve and an exposed steel penstock 13 ft. in diameter by 230 ft. long to a dis-

Fig. 8. The Vigario canal seen from a point above the Vigario tunnel intake structure

charge structure which empties into the Vigario reservoir.

Five pumps are scheduled for installation at Vigario as against the four at Santa Cecília, partly to cope with the additional water from the Piraí River and partly to meet operating conditions. Unlike the Santa Cecília pumps, those at Vigario will not operate continuously. Owing to their much higher power requirements they may be shut down during peak loads, and if necessary may be operated in reverse as generators to carry system peaks up to a maximum of 50,000 kW. The fifth pump, therefore, provides a reserve to recover any water used by these units for power generation, and to catch up on the flow continuously provided by Santa Cecília. Two pumps are now in service, the third is being installed, the fourth is planned for 1954, and the fifth is unofficially scheduled for 1959.

The Vigario reservoir, lying at 1,306 ft. above sea level, has an area of only 840 acres but its storage capacity is no less than 37,000 acre ft. To form the reservoir two earth dams had to be constructed, one 134 ft. and the other 118 ft. high.

Great care had to be taken in the design and construction of these dams owing to the unsatisfactory nature of the available earth fill, which consisted of decomposed gneiss, requiring constant supervision from the company's geologist and specialists. The dams are of rolled-fill construction. A continuous check was maintained on the moisture content of the material from the borrow pit, and if it departed from the optimum value specified by the consultant the material was either spread out to dry or sprinkled with water to bring it to the required condition.

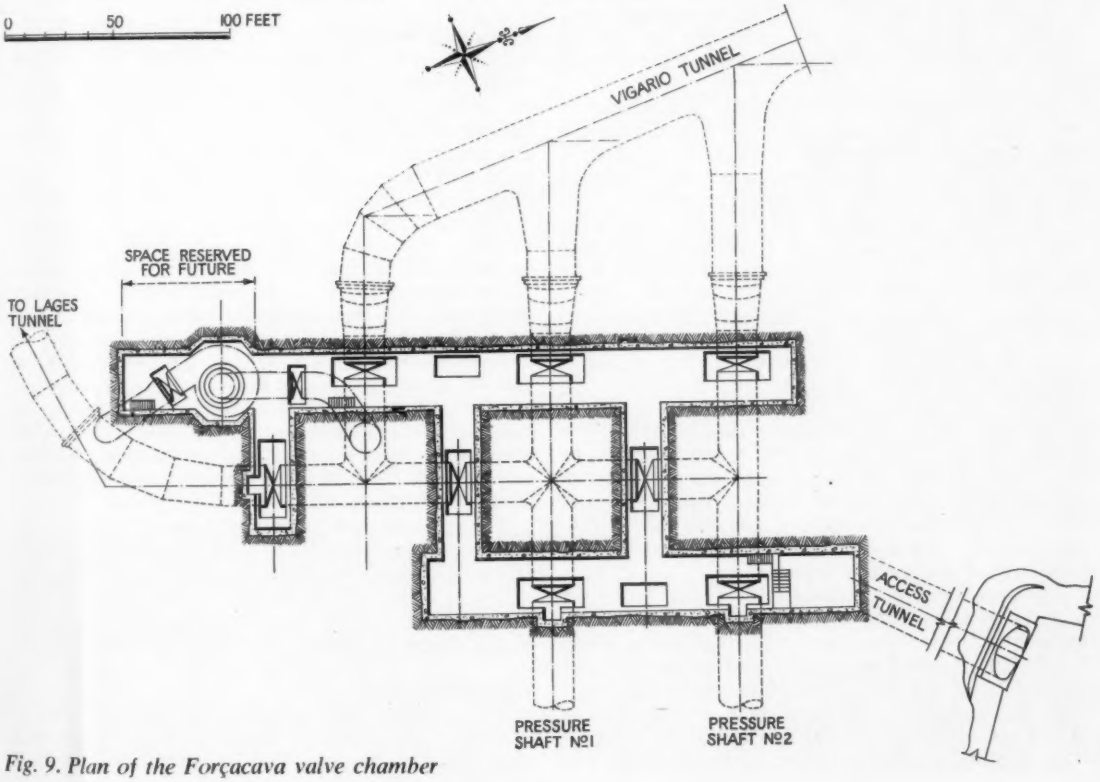


Fig. 9. Plan of the Forçacava valve chamber

The humus covering the dam sites was a black organic muck which offered practically no resistance to sliding, and this overburden had to be stripped down to a foundation of clean rock. In view of the fissured character of this foundation, tests were made to ascertain the feasibility of putting down a grout curtain, but the quantity of grout required would have been excessive. Vertical filter wells were therefore sunk, 6 ft. 6 in. apart, to a depth of 46 ft. to sound bedrock. To protect the downstream side of the dam from excessive saturation a horizontal rock filter was laid over the downstream foundation rock, and a vertical sand filter was incorporated near the centre line of the dam immediately above the filter wells. Drain pipes from this sand filter lead to a permanent sump.

From the Vigario reservoir the flow is by gravity to Forçacava valve chamber through the Vigario canal and tunnel. The canal is 4,500 ft. long, is 46 ft. wide at the bottom, and has 3 : 2 side slopes. It is chiefly in earth and is concrete lined. At the entrance to the tunnel is a reinforced-concrete intake structure equipped with racks and two wheel-mounted gates. The tunnel is 1,970 ft. long and 615 sq. ft. cross-sectional area, and has a discharge capacity of double the general diversion capacity to take into account the system load factor.

Fig. 10. The Forçacava pressure shaft under construction

The underground valve chamber is connected to a new surge chamber and thence to the tunnel from the Lajes reservoir just upstream of the valve house controlling the Fontes power station; it has been designed for the utmost flexibility in routing the water to meet the operating requirements in the various seasons. During the rainy season with run-of-river plants at full output, the offtake from the Lajes reservoir will be shut off except for the water supply in Rio de Janeiro, and the reservoir allowed to fill, both the Fontes and the Forçacava stations being run on Paraíbi-Piraí water. In the dry season with run-of-river plants at reduced output, future units beyond Forçacava will operate on stored water from Lajes reservoir. In intermediate seasons the Fontes station load will be divided between Lajes water and Paraíba-Piraí water in accordance with the operating requirements. In an emergency all units can be supplied from the Lajes reservoir. At present, work is proceeding on the Forçacava station while the Fontes station is being supplied with Paraíba-Piraí water.

To meet these requirements the tunnel from the Vigario reservoir trifurcates at the valve chamber, the three branches feeding a sectionalised manifold which has outlets to the Lajes tunnel and to the pressure shafts feeding the Forçacava plant and future units The arrangement is shown in plan in Fig. 9. The valves are 17 ft. in diameter and are of the butterfly type operated by high-pressure oil servomotors, and so far, five of these valves have been installed.

Forçacava Station

It was originally intended to utilise the diverted water by extending the existing Fontes power house, but such a course would have been attended by serious difficulties. The valley is so narrow as to preclude any material extension to the station, and it would have been necessary eventually to remove the eight older sets to make room for some of the new ones.

After a careful study based on Swiss and Swedish practice, it was seen to be more economical to build an underground station served by an underground valve chamber and a single pressure shaft, provision being made for the installation of future units, with pressure shaft, as soon as required.

Forçacava will have two 35,000 kW and four 65,000 kW generating units, and with its aggregate capacity of 330,000 kW will be one of the largest underground stations in the world. The future units will have an even larger aggregate capacity of 390,000 kW. The turbines will be of the Francis type, operating under a head of 1,130 ft.

The pressure shaft is 20 ft. in diameter and 1,312 ft. long and is concrete lined to a minimum thickness of 10 in. It is furnished with a welded steel lining designed to withstand 30 per cent. of the water pressure except at the distribution manifold serving the power house, where it is designed to carry the full pressure.

Electrical System

The original plant at Fontes station generated at 6,000 V three-phase 50 cycles, and the power was transmitted to the Frei Caneca substation over four

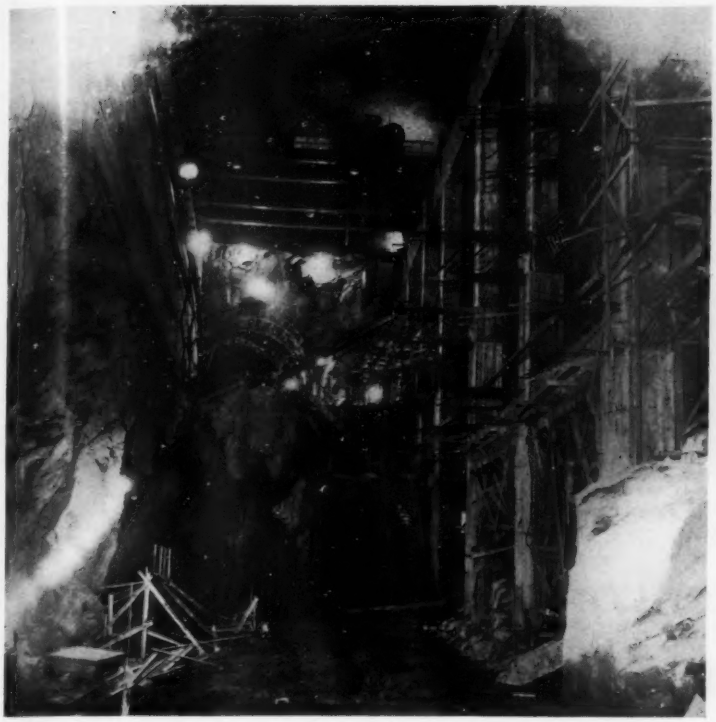


Fig. 11. The eastern end of the Forçacava underground station under construction

lines at 40 kV. In 1913, when the station was enlarged, the transmission voltage was raised to 88 kV and a new substation was built at Cascadura. Additional transmission capacity at 132 kV was added in 1940. When the Ilha dos Pombos plant was built it was originally connected to Cascadura by two 88 kV circuits, but the voltage was raised to 132 kV in 1930, and two further 132 kV lines were constructed in 1936 and 1950 respectively. In 1950 a 230 kV transmission line was constructed between Fontes and Cubatão station in São Paulo, permitting an exchange of power between São Paulo at 60 cycles and Rio de Janeiro at 50 cycles through a frequency-changer station at Apericeda. The Forçacava stations will be coupled into this system.

In the near future it is proposed to build a further 90,000 kW station using the remaining head between the Fontes-Forçacava tailrace and sea level.

When the scheme is complete, the generating capacity of the scheme will be raised from 1,570 million to over 4,000 million kWh per annum—sufficient to keep pace with the anticipated load growth of the Rio system until at least 1960.

Progress and Acknowledgments

The development is being financed through a loan from the International Bank of Reconstruction, and the work is being carried out by Morrison-Knudsen do Brasil. The first stage of the project, covering the actual diversion, was inaugurated last year, and Forçacava is now under construction, the first unit being expected to be put into service this September.

This article is published by kind permission of Brazilian Traction, Light and Power Co. Ltd., Toronto, in association with Companhia Brasileira Administradora de Serviços Técnicos (COBAST), São Paulo, to whom we are indebted for the necessary technical data and illustrations. We also derived much valuable information from a paper " Piraí Diversion Project to fill Rio de Janeiro's Power Needs up to 1960 " by A. J. Ackerman, F. T. Matthias and G. O. Vogan, read before the American Society of Civil Engineers and published in the Society's journal *Civil Engineering*, October and November, 1951.

Allis-Chalmers Annual Review. The 1952 Review of the General Machinery Division is a 46 page brochure covering power generation and distribution, forest products, food, metals, chemicals, petroleum, mining and quarrying, marine equipment, public works, national defence, research, and export. Mention is made of the reversible pump-turbine for the T.V.A. —the largest in the world—and of other units of this type, including those for the Paraíba-Piraí diversion.

Engraving, Die Sinking, Pressing, &c. A catalogue from Millett, Levens (Engravers) Ltd., Whadcoat Street, London, N.4, introduces us to a specialised type of product that has countless applications in engineering and industry. This firm is equipped to produce all kinds of dials, scales, instrument panels, wiring-diagram plates, labels, marking devices and so forth in any required finish in either metal or plastic. They can also undertake die sinking, metal pressing, and special machined parts. The standard of production of the catalogue is exceptionally high and gives an excellent idea of the appearance of some of the finished products.

Switchgear. Cooke & Ferguson Limited, Manchester, England, have sent us two new catalogue sections. One deals with type UD single-busbar air-insulated totally enclosed metalclad switchgear units with vertically isolated circuit breakers rated at 350 MVA at 11 kV. The other relates to the D5 low-oil-content circuit breaker rated at 350 MVA at 6·6 kV and 500 MVA at 11 to 22 kV.

"Dominion Engineer." No. 2, 1953, of this well-known house journal is entitled " Highlights of 1952 " and includes a description of the huge 42/53 ft. boring mill built by Dominion Engineering Co. Ltd. and installed in their Lachine plant to handle work of the size of the twelve 105,000 h.p. Francis turbines they are building for the Sir Adam Beck station at Niagara Falls. The mill weighs 500 tons, is 45 ft. high and 56 ft. wide, and the turntable will support 200 tons.

Fig. 1. The Poringalkuthu dam under construction

The Poringalkuthu Hydro-Electric Scheme

Following his description of the Chalakudy scheme in our June issue, R. Dorai Rajan gives details of the Left Bank development now under construction.

THE first power project to benefit the Cochin portion of the Travancore - Cochin State is the Poringalkuthu hydro-electric scheme. This scheme, known as the Left Bank Scheme, envisages the ultimate development of 48,000 kW in two stages, at Poringalkuthu, on the Chalakudy river. This is the largest perennial stream in the Cochin territory, and 40 miles from its source and 26 miles from the Chalakudy railway station a reservoir has been constructed to regulate and divert its flow through a tunnel to the power house. The river forms a series of cascades which have a total fall of 600 ft., and the scheme is planned to utilise this head for power development. In the first stage, the installed capacity of the plant will be 24,000 kW and is estimated to cost Rs. 260 lakhs.

The scheme was first investigated during 1918-32 by Mr. S. G. Forbes, then Chief Engineer for Electricity, Mysore, the Westinghouse Electric International Company, and Rendel, Palmer and Tritton, consulting engineers. Sir Henry Howard, the first Chief Engineer for Electricity, Madras, and later consulting engineer to several States in India, was the last to investigate it during 1946-48 and suggested the present site as being the most economical. Work was started in 1947, construction and investigation proceeding side by side.

The Poringalkuthu dam, known as the Lower Dam, is a straight gravity structure, constructed in rubble masonry, 1,200 ft. long and 86 ft. above river bed, impounding a gross storage of 1,130 million cu. ft. Its maximum width at foundation level is 93 ft.

In order to dispose of floods which may reach a maximum of 80,000 cusecs, draining a basin of 383 square miles with an annual rainfall of 160 in., seven crest gates of the lowering type, 40 ft. long, 15 ft. deep and capable of discharging 52,000 cusecs, are installed on the spillway on the left flank, in addition to four underwater sluices 18 ft. 9 in. high and 8 ft. wide, which discharge the balance. The crest of the spillway is 66 ft. above river bed. All the spillway gates and underwater sluices were supplied by Ransomes and Rapier Ltd., of Ipswich. The full retention level and maximum flood level are to be kept the same in order to prevent damage to roads and bridges at Anakayam, five miles upstream. The reservoir, of over 700 acres, will have a shoreline of 13 miles and will extend three miles upstream of the dam. The foundation of the dam has been taken down to hard rock 35 ft. below river-bed level, and core boring, including the injection of a grouting curtain and blanket grouting, has contributed to consolidate the foundations. A cut-off trench, lined with concrete, is also provided at the heel of the dam to check water percolation under foundation and also to serve as a key. The masonry content of the dam is 2·1 million cu. ft. and the cost Rs. 54 lakhs.

Water from the reservoir is led through a tunnel cut mostly in rock across the intervening hill for a distance of 3,995 ft. The tunnel has a rectangular lower section 13 ft. wide and 6 ft. high, and is finished with a semi-circular top. The cross-sectional area is

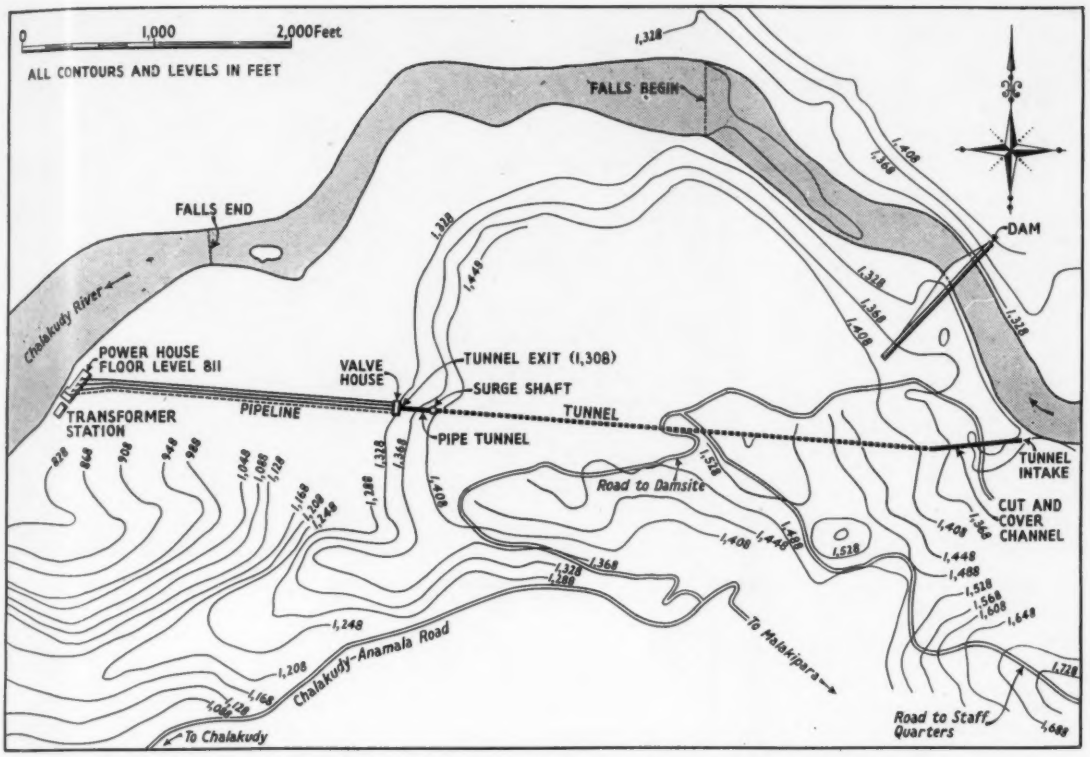


Fig. 2. Site plan of the Poringalkuthu, or Left Bank, scheme on the Chalakudy River

144·4 sq. ft. To reduce friction, the tunnel has been finished with a concrete lining 6 in. thick. The capacity is 1,200 cusecs at a regulated velocity of 8 ft. per sec. A reinforced-concrete cut-and-cover channel, 380 ft. long, connects the intake works with the tunnel portal. The intake works to the tunnel comprise a masonry entrance portal, two inlet gates each 10 ft. by 8 ft., and trash racks. These gates were also supplied by Ransomes and Rapier Ltd. and are operated by winches. The cost of the tunnel, which was constructed departmentally, was Rs. 24 lakhs; it is claimed to be the cheapest tunnel in India at Rs. 325 per foot.

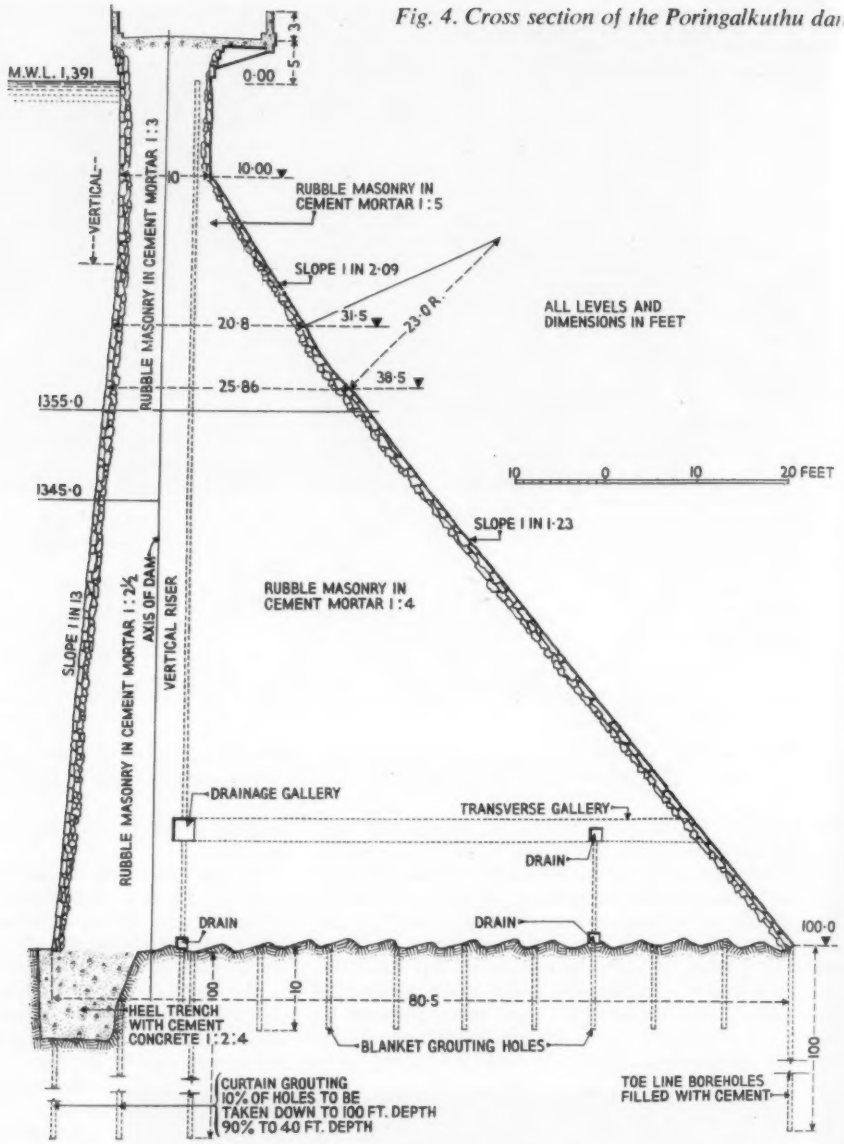
On the other side of the hill, 144 ft. from the tunnel exit, is located a simple surge tank cut in rock, 93 ft. in height and having a finished internal diameter of 50 ft. It will be lined with concrete and be finished with a domed top.

Two low-pressure pipes, each 8 ft. 6 in. internal diameter, are laid for a distance of 144 ft. from the surge tank to the tunnel exit. Here one of the pipes trifurcates into branches of 52 in. internal diameter and having a capacity of 200 cusecs. Each branch constitutes a penstock for one machine, butterfly valves and venturi meter tubes being fitted at the valve house. The second 8 ft. 6 in. diameter pipe divides into two branches which are continued up to the butterfly valves and blanked off for the first stage. The butterfly and air valves were supplied by Glenfield & Kennedy Limited, through Boving and Co. Ltd., the venturi tubes being situated about 40 ft. downstream of the first anchor block.

Fig. 3. Penstock pipes awaiting erection

The head from the tunnel exit to the turbines is 600 ft. and the three penstocks of the first stage are 2,600 ft. long and are held in position by nine concrete anchors along the hillside, the maximum inclination being 20°. Each 2 ft.

Fig. 4. Cross section of the Poringalkuthu dam



section of pipe has an average weight of 3½ tons but the sections for the lower reaches, which were tested to 2,000 lb. per sq. in., weigh up to 9½ tons. The cost of the penstocks, which are supplied by Ferrum Ltd., was Rs. 51 lakhs.

A haulage track is laid along the pipeline and is operated by two winches supplied by John M. Hendersons Ltd., Aberdeen, and driven by Higgs motors. The control panel was supplied by Edward Holme Ltd., of Altrincham.

Four air-compressor sets by Broome and Wade Ltd., driven by 11 h.p. Metrovick motors are used for tunnelling work, the grouting pumps and for a sand-washing plant. This plant is an adaptation of a Patterson washing plant to suit the site conditions; it consists of a rectangular masonry tank 12 × 8 × 4 ft. with overflow and draining arrangements and with pipe grid systems for water and compressed air at the bottom. Holes ¼ in. in diameter and staggered 6 in. apart are provided on the lower side of the pipes for the water manifold, while holes $\frac{1}{16}$ in. in diameter and 4 in. apart are provided for the air distribution. A layer of metal graded from 2 in. to ½ in. and 6 in. deep, is also provided at the bottom, just covering the top of the grids to prevent frequent choking of the holes. As soon as the unit is charged with the raw sand, the water pumps are started up, and care is taken to see that the air valves and drain valves are properly closed. When sufficient water has been admitted compressed air is let in for a few minutes until just at the point when the tank is on the point of overflowing the shutters, the air valves are partially closed and the shutters lifted, thus flushing out the scum, floating matter and mud. When the water has fallen to the level of the sill the shutters are put back in position and the tank is again filled with water.

Fig. 5. Inlet portal of the intake tunnel

Fig. 6. Spillway section of the dam under construction

This process is repeated until the sand is completely washed, after which the water is allowed to drain off by opening the scour valve.

The power house is of reinforced-concrete construction with hollow blocks in panels, 125 ft. long, 65 ft. wide and 49 ft. high and accommodates three turbo-generator sets and indoor switchgear. A 70 ton overhead travelling crane has been installed, together with a 5 ton auxiliary hoist.

Each turbine consists of a 13,500 h.p. vertical reaction wheel coupled to a 8,000 kW M.C.R. 11 kV 0·85 power factor 3 phase, 50 cycle 600 r.p.m. alternator. One unit will serve as a standby. A house service unit is also provided consisting of a 150 h.p. horizontal impulse machine coupled to a 125 kVA generator. Three 10 MVA. 11/66/110 kV transformers are provided.

The turbines are supplied by Charmilles Engineering Works, Geneva, the generators, switchgear and transformers being of The English Electric Company's manufacture. The total cost of machinery in the power house is Rs. 69 lakhs, the cost per kW of installed capacity being Rs. 1,367.

The transmission line connects with Chalakudy 26 miles away and from here the supply will be connected with the Pallivasal Grid. It is proposed to construct the transmission line departmentally.

Work on the dam is nearing completion, and the tunnel is bored for the full length and concrete lined. All the penstocks have arrived and are ready for erection. At the moment of writing it is expected that installation of the generating machinery will commence in May 1953 and that the generators will be commissioned in sequence, the whole scheme being scheduled for completion by June 1954.

As is only natural in a terrain like this, engineers had to encounter and overcome many obstacles, not the least among them being the menace of wild animals, particularly elephants, which often undid work that had been accomplished; malaria and the transport of heavy machinery over primitive tracks had also to be contended with.

Mr. S. J. Bruford, for some time Chief Engineer for Hydro-Electric Development, Cochin State, was in charge of the project in the early stages. On his retirement Mr. George Oommen, who has lately returned from America, took over as Chief Construction Engineer and is assisted by Mr. O. J. Cherian, Executive Engineer, who heads the constructional staff on the site.

Fig. 7. Outlet portal leading from surge tank

Calculating Flow by Relaxation Methods

The solution of problems of fluid flow by relaxation methods, with particular reference to flow over sharp-crested weirs

By W. WRIGHT, B.Sc. (Eng.), Ph.D., A.M.I.C.E.

IN problems of fluid flow it is usually a simple matter to formulate the general equations of flow, but in practice the boundary conditions usually render the problem intractable by ordinary methods of analysis. Problems of this nature are usually solved (a) by the use of models, (b) by graphical methods, or (c) by methods of successive approximation. The method of successive approximation used in this article is one which is applicable to a number of flow problems, notably flow over weirs, flow over spillways and flow through orifices.

To illustrate the method the case of flow over sharp-crested weirs is treated. Two cases are considered: (a) Fully aerated nappe; (b) Non-aerated nappe.

The commonest method of gauging the flow of water in channels and streams is by means of a weir, usually with a sharp crest (Fig. 1). The head of water

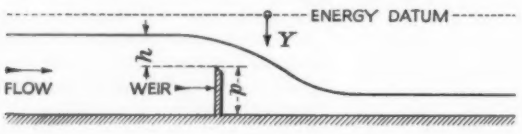


Fig. 1

over the weir is measured h and the flow computed from the formula Q quantity (per unit breadth)$= C\sqrt{2g}\,h^{\frac{3}{2}}$ where, except for very small values of h, the value of C is constant for a fixed $\frac{h}{h+p}$ ratio and is usually determined empirically.

The author's purpose is to show how the value of C may be found analytically using relaxation methods.[1] The method is essentially the same as that used previously by Southwell and Vaisey[2] in the solution of "free streamline" problems. Numerical values of the stream function ψ are computed at the nodal points of a square network, and once these are known the velocity, quantity and the value of the coefficient C can be calculated.

Assuming the system is conservative we have:

$$\frac{p}{\rho}+\tfrac{1}{2}q^2+gy=\text{const.} \quad \text{Bernouilli} \quad (1)$$

y being measured upwards from some datum level, so that at all points where p has a constant value p_0

$$q^2+2gy=\text{const.}=2gy_0 \quad (2)$$

y_0 being the highest level to which such points can extend (i.e. "stagnation level," at which the velocity $q=0$ and the pressure p_0.

In (2) $q^2=u^2+v^2=\left(\frac{d\psi}{dx}\right)^2+\left(\frac{d\psi}{dy}\right)^2$ where u and v are component velocities in the x and y directions respectively. If we now reverse the directions of x and y, and measure y downwards from "stagnation level." and x from right to left, equation (2) simplifies to:

$$q^2=2gy \quad (3)$$

Along any streamline ψ is constant, so q is measured by its normal gradient $\frac{d\psi}{dn}$, so that on any free streamline we have the double boundary condition $\psi=$const. (4)

$$\left(\frac{d\psi}{dn}\right)^2=\left(\frac{d\psi}{dx}\right)^2+\left(\frac{d\psi}{dy}\right)^2=q^2=2gy \quad (5)$$

Also we have the condition that ψ is Laplacian everywhere, i.e. $\nabla^2\psi=\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}=0$ (6)

Elimination of Dimensional Factors

Let D be some representative dimension of the rigid boundaries.

Then let $x=x'D$, $y=y'D$, $n=n'D$, $\psi=\psi'\sqrt{2gD^3}$.

Then, for a free streamline (on which the pressure is p_0) we have in place of (4)

$$\psi'=\text{constant} \quad (7)$$

$$\left(\frac{d\psi'}{dn'}\right)^2=\left(\frac{d\psi'}{dx'}\right)^2+\left(\frac{d\psi'}{dy'}\right)^2=q'^2=y' \quad (8)$$

Suppressing the dashes for x, y, n, q and ψ which will now be understood to be non-dimensional, we have generally

Along any streamline $\psi=$constant.

On a free streamline

$$\left(\frac{d\psi}{dn}\right)^2=\left(\frac{d\psi}{dx}\right)^2+\left(\frac{d\psi}{dy}\right)^2=q^2=y.$$

The estimation of normal gradient is made easier by the fact that the boundary is a free streamline, and therefore $\frac{d\psi}{dx}=\cos(xn)\,\frac{d\psi}{dn}$; $\frac{d\psi}{dy}=\sin(xn)\,\frac{d\psi}{dn}$

Two cases were considered by the author:—

(a) No air admitted to the nappe when the boundary conditions are as shown in Fig. 2. The velocity $\left(\frac{d\psi}{dy}\right)$ across the two vertical boundaries was assumed constant; i.e. ψ varies lineally from zero on the upper boundary to ψ_1 on the lower.

The ratio of D/d was assumed so as to determine the position of the energy datum, a numerical value (80) was assigned to ψ_1 on the lower boundary, and

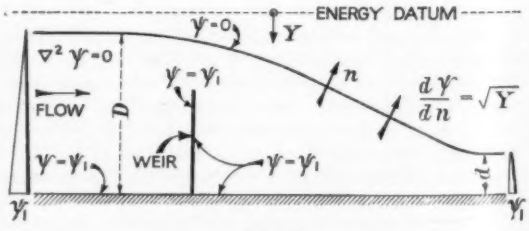


Fig. 2

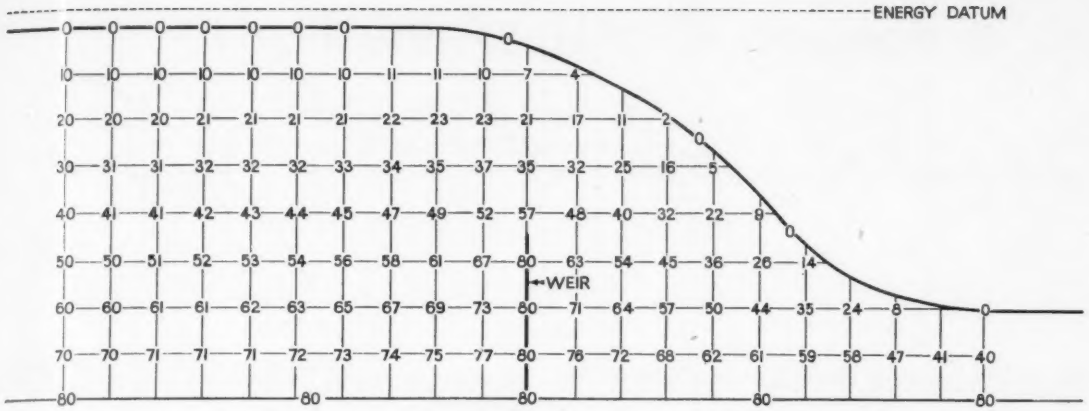


Fig. 3

the value of ψ on the upper boundary was taken as zero for convenience. Relaxation was carried out in the usual way using a square network (see Appendix). A start was made by assuming the shape of the upper boundary and also the weir height and then modifying them in the light of the trial solution until the residuals were negligible and the error in comparing the normal gradient with $\sqrt{y}$ was <1 per cent. The solution, which yields a value of 0·53 for C with an $\frac{h}{h+p}$ ratio of 0·55 is given in Fig. 3.

(b) Air at atmospheric pressure admitted to the nappe. In this case there are two boundaries on which the normal gradient must be made equal to $\sqrt{y}$. The other conditions are the same as before (see Fig. 4). The procedure was exactly the same as that used for case *(a)* and the value of C was found to be 0·49 for an $\frac{h}{h+p}$ ratio of 0·60. The solution is given in Fig. 5.

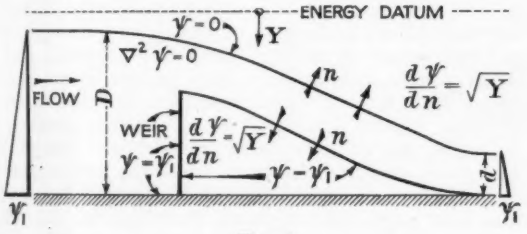


Fig. 4

Conclusions

The value of 0·49 for the coefficient C when the nappe is fully aerated and the $\frac{h}{h+p}$ ratio 0·60 compares favourably with the value given by Rouse[3], and this may be said to justify the accuracy of the method.

In the case of the unaerated nappe the same D/d ratio was assumed and this made it necessary to raise the height of the weir slightly, thus changing the $\frac{h}{h+p}$ ratio to 0·55. The coefficient C in this case was 0·53 as compared with a value of 0·48 for the same $\frac{h}{h+p}$ ratio with the nappe aerated (see Rouse[3]).

The general conclusion indicated is that non-aeration of the nappe may be expected to increase the discharge by about 10 per cent. as compared with an aerated nappe when the head over the weir h is of the same order as the weir height p.

Appendix

The following is a brief resumé of the salient points in the relaxation technique for solving Laplace's Equation.

The stream function ψ is Laplacian

i.e. $\nabla^2\psi=0$ or $\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}=0$

We divide up the zone in which a solution is required into a square network of side h. The point 0 (see Fig. 6) is a typical node, and if we take the origin at point 0 the finite difference form of the

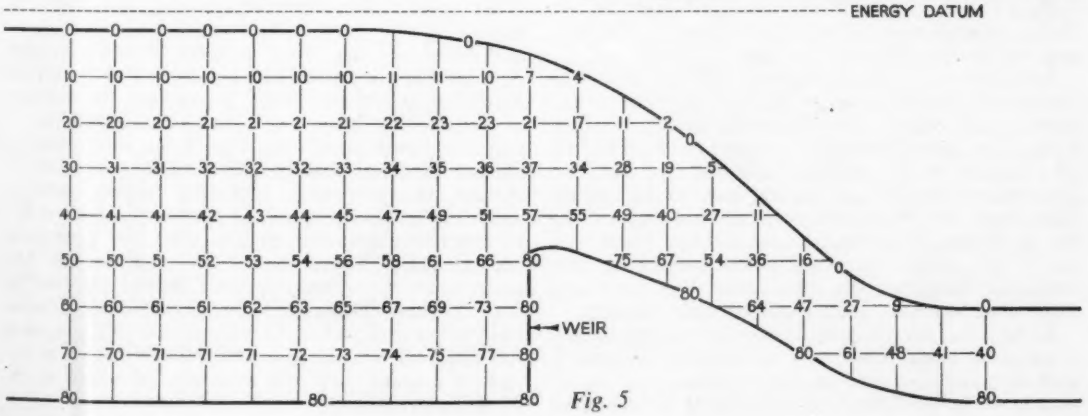


Fig. 5

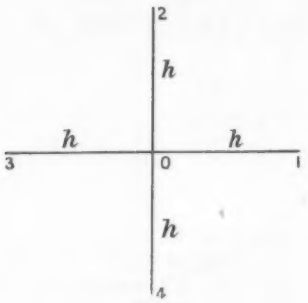


Fig. 6

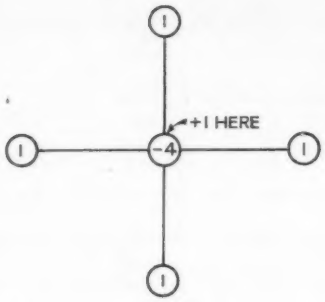


Fig. 7

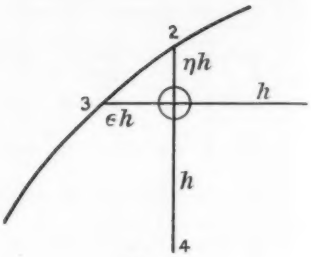


Fig. 8

governing equation, accepting an error of order h^2, will be: $-4\psi_0+\psi_1+\psi_2+\psi_3+\psi_4=0$
and if we satisfy this equation at every nodal point we have the required solution.

In solving by relaxation we write the equation in the form $F_0 = -4\psi_0+\psi_1+\psi_2+\psi_3+\psi_4$
where F_0 is defined as the residual at the point 0. The procedure is to guess values for ψ at each nodal point, to calculate the resulting residuals and then by suitable alterations of the initial guessed values of ψ to make these residuals zero or negligible. The effect of unit change in ψ_0 is to change F_0 by -4 and the surrounding residuals F_1, F_2, F_3 and F_4 by $+1$. This is shown diagrammatically in Fig. 7, in the form of a relaxation pattern.

Curved Boundary

When the boundary is curved the relaxation net does not, in general, intersect the boundary at a nodal point and this calls for a modification to the residual equation for points immediately adjacent to the boundary.

In the problem dealt with in this paper the maximum number of strings cut short by the boundary at any point was two, and in such a case it can be shown that the appropriate formula for calculating the residual F_0 (Fig. 8) at a point immediately adjacent to the boundary is:—

$$F_0=\frac{2}{1+\epsilon}\psi_1+\frac{2}{1+\eta}\psi_4+\frac{2}{\epsilon(1+\epsilon)}\psi_3+\frac{2}{\eta(1+\eta)}\psi_2-\left(\frac{2}{\epsilon}+\frac{2}{\eta}\right)\psi_0$$

REFERENCES

[1] "Relaxation Methods in Theoretical Physics." Southwell R. V. Oxford University Press. 1st Edition, 1946.

[2] "Fluid Motions characterised by free streamlines." Southwell and Vaisey. *Proceedings of the Royal Society* A240. 1946. pp. 117-161.

[3] "Engineering Hydraulics" Rouse H. John Wiley & Sons. 1st Edition, 1950. p. 50.

Experimental Wind-Driven Generator

The 100 kW experimental wind-driven generator being built by Enfield Cables Limited for the British Electricity Authority is well on its way to completion, and we recently had an opportunity to inspect it during erection at its temporary site at St. Albans. It will operate on the Andreau depression principle, in which the propeller acts as an air exhauster which operates an air turbine by suction, but the present set has been designed from first principles by Enfield Cables Limited with the collaboration of their subcontractors, de Havilland Propellers Limited and The English Electric Co. Ltd.

Although the overall efficiency of the Andreau system will almost certainly be less than that of the more usual geared drive, important compensating advantages are claimed for it, notably the high degree of reliability to be expected and the fact that the generator is carried near ground level instead of up aloft. The 100 kW wind-driven set now being built for the North of Scotland Hydro-Electric Board will be of the geared type, and a comparison of performance between the two when the necessary experience has been gained will be most valuable.

At the present stage capital and other costs are largely a matter of conjecture, but it is estimated tentatively that on a commercially produced machine an overall cost of 0·25d. per kWh will be achieved, as compared with a fuel cost for a British steam station of 0·4d. per kWh. On this basis wind power would show costs of the same order as some water-power schemes, but two difficulties have to be met. In the first place the firm power is nil, and thus for industrial and public supply wind power is only feasible when connected to a network based primarily on other types of prime mover. Secondly, the power concentration is small, and a very large number of windmill generators would be needed to make any appreciable contribution to a supply network. For parallel operation with hydro-electric plants, therefore, the role of wind power would seem to be that of a small-scale water saver rather than of providing any access of capacity.

Wind power may find its most promising outlet in areas that are too remote, and for which the power requirements are too small, to warrant the erection of transmission lines, but even here the problem of non-firm power would remain. As an alternative to the use of diesel standby plant, various methods of storage are proposed, including battery storage, water electrolysis to produce hydrogen which is fed to internal-combustion engines, and the generation and storage of steam for use in steam engines; but quite apart from the additional capital involved in any of these proposals, the circumstances would need to be exceptional to warrant the inclusion of a thermal cycle with its low conversion efficiency at the end of a wind cycle the efficiency of which is yet to be ascertained.

The Isère-Arc Development

A description of one of the important projects of Electricité de France, with special reference to the design of the dam, surge chamber and pressure shafts

By DR. CHARLES JAEGER

PART TWO

Surge Tank and Emergency Valves

The surge tank is a structure of exceptionally large size. It consists of a vertical shaft of 17·00 m. diameter, 51 m. deep, representing about 15,500 cu. m. total volume (including the expansion chambers). In the first project five additional horizontal galleries at different levels were planned. These have finally been reduced to two large expansion chambers at the top (Fig. 11). The bottom of the tank is at a level of 437·32 m. and a restricted orifice (throttle) is provided which is arranged laterally to the main tunnel instead of above it. A special feature maintains the required pressure above the main tunnel (see Fig. 11). These arrangements have definite advantages, the chief being that the construction of the tank does not interfere with the construction of the main tunnel. Furthermore, water levels in the tank are allowed to fall lower than with a more conventional design of tank with a restricted orifice. Immediately after passing the surge tank, the main tunnel divides into two galleries which then dive vertically into the rock forming two parallel pressure shafts. Two butterfly

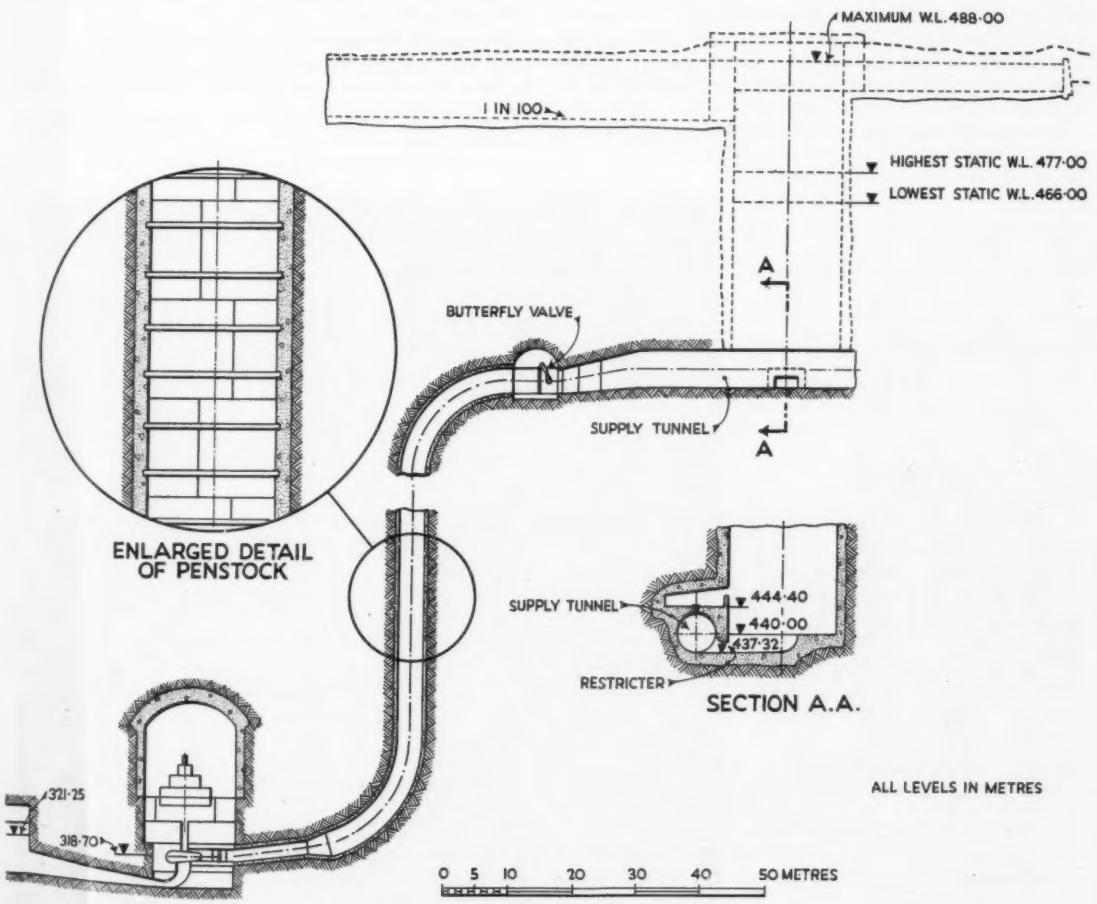


Fig. 11. Arrangement drawings of surge tank, underground penstock and power station

valves for the emergency closing of the two shafts are arranged in a separate gallery at the top of the shafts. The removal of these valves is effected by means of a hook, anchored in the rock, and a pulley block. This arrangement of the throttled surge tank (shown in Fig. 11) with lateral orifice and the two butterfly valves is very convenient and saves considerable excavation, especially for very large developments. It is to be expected that it will be repeated in future for other power schemes with large surge tanks.

Steel-lined Pressure Shafts

The two steel-lined vertical pressure shafts, Figs. 11 and 13, have an internal diameter of 3·70 m. The thickness of the plate varies from 12 mm. at the top to 16 mm. at the bottom (level 318·70 m.). With the reservoir at level 471 m., the maximum static pressure on the shaft will be 52·3 m. The plate thickness is increased to 18 mm. in the last bend, the main vertical pipe being diverted horizontally and divided into two 2·60 m. diameter pipes with plate thickness of 23 mm. There is a transition Y-shaped piece between the larger pipe and the two smaller pipes (Fig. 13). The four butterfly valves closing the 2·6 m. diameter pipes are inside the main power-house building. The Y-piece is designed on the same principle as that at the Loch Sloy station (Scotland) with an inside vertical rib to counteract the distorting action of the hydrostatic thrust. This Y-piece was welded on site and tested before the concrete was poured in the space between the rock and the steel shell. Fig. 13 shows the piece being erected.

The minimum diameter of the vertical bore in the rock is 4·50 m., which leaves a margin of 0·40 m. for the concrete between the pipe and the rock. The steel lining is divided into sections of 3 m. height, each of which is reinforced by two angle-iron hoops welded to the lining (dimensions of the angles 100 × 100 × 10 mm. for the upper part of the lining, 120 × 120 × 12 mm. for the lower).

All the metallic linings are being lowered into position through the vertical shaft. Concrete is being thoroughly vibrated when being placed. The erection begins at the bottom of the pipe.

It is worth while comparing the Isère-Arc steel-lined pressure shaft with other well-known structures of the same type. This is done in Table I. In this table, the plate thickness refers to the base of the pipeline, where the head is maximum. The tensile stresses are calculated for the maximum static head (disregarding the dynamic pressure from water hammer), assuming that the rock is taking no pressure, the plate lining taking the full load. The figure of 1,750 kg. per sq. cm. assumed for the design of Isère-Arc compares with the figures of 1,600 to 1,800 kg. per sq. cm., which were the basic assumptions for the design of several Italian pressure shafts (Edison group)*. It is likely that the quality of the steel being used for all these projects is comparable, the ultimate tensile stress for the steel being probably between 4,800 and 5,000 kg. per sq. cm. The difference must therefore be a reflection of the degree of confidence of the designers in the ability of the rock to take part of the load. Most of the Italian projects

* Ch. Jaeger: "A Study Tour in the Alps," WATER POWER, May/June, 1951.

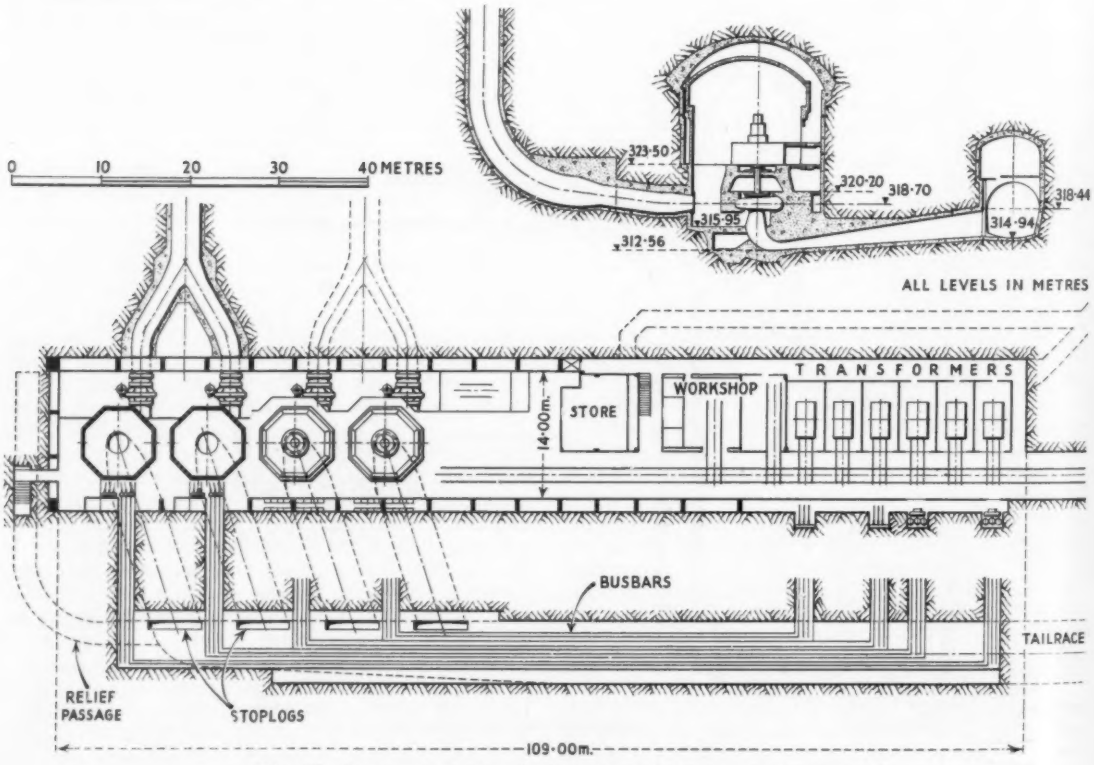


Fig. 12. Plan and sectional elevation of the power station

were in fissured limestone of very uneven quality. The Innertkirchen pressure shaft is excavated from compact and nearly faultless gneiss. Isére-Arc is located in gneiss and micashists of good quality.

TABLE I.—CHARACTERISTIC DATA ON SOME IMPORTANT STEEL-LINED PRESSURE SHAFTS.

	Static head	Pipe diameter	Plate thickness (max.)	Circumferential stress
	m.	m.	mm.	kg./sq. cm.
Handeck I (Switzerland)	550	2·10	20	2,885
Innertkirchen (Switzerland)	672·30	2·40	20	4,030
Isère-Arc (France)	152·30	3·70	16	1,750
Kemano (Canada)	790	3·35	49·3	2,670

Comparing the capacity of these pressure shafts it will seem that they are designed for the following maximum output:

Innertkirchen 1 shaft for $5 \times 56{,}000 = 280{,}000$ h.p.
Isère-Arc 2 shafts each for $2 \times 45{,}000 = 90{,}000$ h.p.
Kemano* 4 shafts each for $4 \times 140{,}000 = 560{,}000$ h.p.
(altogether 2,240,000 h.p.).

Thus the Kemano figure of 560,000 h.p. per shaft exceeds the 500,000 h.p. per shaft which, only two years ago, was considered to be the greatest possible rating of pressure shafts. This is also approximately equal to the greatest possible output of a single prestressed pipe according to the French expert Ferrand.

* F. L. Lawton and J. S. Kendrick: "Nechako-Kemano-Kitimat Hydro-Electric Power Development and Aluminium Reduction Plant." *The Engineering Journal*, Montreal, Vol. 35, No. 9, Sept. 1952, and L. L. Wise: "World's Largest Underground Power Plant." *Eng. News Record*, Nov. 13, 1952.

Fig. 13. Erecting the Y-piece at the bottom of the pressure shaft

Table I requires some further comment. A theory has been developed† for calculating the load distribution between the steel lining and the rock when the pipe is filled with water, causing an inner pressure on the steel lining. All the authors calculating the load transmission to the rock have assumed the elastic deflection of the pipe diameter to be equivalent to the elastic yielding of the rock. This condition of equal elastic deformation enables a system of simple equations to be solved. Unless the diameter of the pipe is great and the pressure high (e.g. Innertkirchen and Kemano) the stress in the steel lining is kept reasonably low and the load is really transmitted to the rock where high tensile stresses develop in a circumferential direction

Recent research work has proved that there is a certain amount of prestressing in the rock. The design of the lining should be such that the circumferential stresses in the rock are compensated by its compressive prestressing. Furthermore, it seems that grouting of the rock has a great influence on the final stability of the construction. One test was made at Isère-Arc to ascertain the amount of prestressing existing in the rock there, but the engineers on the site were unable to say how this measurement compares with others to be made at the same time elsewhere in France.

Outside pressure created by water seeping through the rock is of great importance for the stability of the steel lining. The steel lining of the pressure shaft at Handeck II (Handeck II belongs to the same group of stations as Handeck I and Innertkirchen)‡ was calculated on external water pressure. We do not know to what extent the outside pressure was considered when calculating the Isère-Arc pressure shaft.

The whole problem of pressure-shaft design and construction has for several years been very controversial, and improvements are continually being made in the methods employed. Fundamental research work is now being carried out in France especially for the future power development of Roselend, which is still at the design stage. This station, in Savoie, will have a total net head of 1,171 m. with a discharge of 42 cu. m. per sec., a 14 km. long pressure tunnel and an installed capacity of $6 \times 96{,}400$ h.p. (578,400 h.p.) on one conduit or pressure shaft. Several alternatives are now being considered for Roselend. If the final design is for a steel-lined pressure shaft, it will be the highest head in the world and comparison of the technique to be used there with that used at Isère-Arc will be of the greatest interest.

There is a definite trend towards underground power stations and any progress in design or construction of such schemes, and

† Ch. Jaeger: "Theorie générale du Coup de Bélier," Paris, 1933, pps. 120-130.

‡ J. Baechlold: "Erfahrungen beim Bau des Kraftwerke Handeck II Schweiz." *Bauzeitung*, Vol. 70, No.14, 11 October, 1952, p. 589.

especially of pressure shafts, must obviously be followed very closely.

The Randens Underground Power House of the Isére-Arc Development

Soundings have shown it to be impracticable to build a surface power house having its foundations on rock as the alluvial formations of the Arc River are of prohibitive thickness. On the other hand it was found that an underground power house could be excavated in rock of excellent quality as was demonstrated by an exploratory gallery. The expense incurred is not greater than it would be for a surface power station.

The power house is 16·80 m. wide and 109 m. long, and is equipped with four vertical reaction turbines (Francis) developing 45,000 h.p. each, coupled to four 36,000 kVA, 10·3 kV, 375 r.p.m. generators. The transformers are also underground. There are two groups of 3—24,000 kVA transformers, 10·3/150 kV. One of the various interesting features of this power station is the new design for the generator support (see Fig. 12). The usual cylindrical generator support transmitting the generator and turbine weight to the speed ring and guide vanes* is replaced here by a cupola which spreads the load to a foundation, the diameter of which is larger than the turbine spiral diameter. The erection of the turbine is, therefore, completely independent of the civil-engineering work and will begin when the spherical generator support is completed.

Fig. 14. A view of the power house under construction

Tailrace Canal

The first 250 m. of the tailrace is underground, after which it flows across the Randens plain for a distance of about 1,000 m., the floor lying about 10 m. below ground level. In order to save the cost of two rows of well points along the canal, a single pump at the canal downstream end is being used for dewatering.

Quantities and Cost

The quantities are given in Table II. The costs (1950 prices) were estimated at 12,500 million French francs. It is expected that the work will be finished at the end of 1953.†

NOTE.—All the photographs published in this article are from Messrs. H. Baranger, Paris, and were sent to us by M. Kobilinsky, Electricité de France.

TABLE II.—LIST OF QUANTITIES FOR THE ISERE-ARC DEVELOPMENT

	Excavation		Concrete	Steel
	Over-ground	Under-ground		
	cu. m.	cu. m.	cu. m.	tons
Dam and intake	60,000	14,000	27,000	300
Reinforced-concrete gallery	200,000	—	34,000	3,000
Pressure tunnel	—	600,000	135,000	800
Surge tank and pressure shaft	—	22,000	5,000	400
Underground power house	—	52,000	17,000	300
Tailrace canal	240,000	12,000	12,000	200
Total	500,000	700,000	230,000	5,000

British Standard for Presentation of Numerical Values. The purpose of this British Standard (B.S. 1957 : 1953) is to promote the adoption of a consistent procedure in the presentation and interpretation of numerical values, particularly in regard to the number of figures to be used and the procedure for rounding. General principles and working rules relating to the different aspects of this subject are set out and illustrated with examples.

* Ch. Jaeger: "Design of Unlined Spiral Casings for Low Head Stations." WATER POWER, Feb./March, 1952, and

† Ch. Jaeger, "The Rhone Development (The Donzére-Mondragon Section)." WATER POWER, January, 1953.

Fig. 1. General view of Cliff power station from downstream

Cliff Power Station

In this second article on the Erne River Development we give an account of the river diversion at Cliff and describe the Cliff power station in some detail.

As stated in our previous article, Cliff power station is located towards the outlet of a shallow gorge about 1 mile below Belleek, the river bed being 180 ft. wide and lying between sheer cliffs 25 ft. high. At the site selected for construction the river takes a sharp bend to the right and widens out, leaving a tongue of rock which forms a convenient abutment for the right-hand end of the dam. The rock is mostly dolomite, but there are a few patches of limestone.

Layout drawings of the station are reproduced in Fig. 6. The civil-engineering works, which were carried out by The Cementation Co. Ltd., Doncaster, comprise a mass concrete gravity dam incorporating the power station on the left, a spillway having three 20 ft. sluice openings, and a right wing 277 ft. long, succeeded by an earth embankment 133 ft. long. The total length of the dam, including the earth embankment, is 690 ft. and the height 60 ft. A salmon pass is provided on the left bank, and an elver pass to the right of the spillway.

Work on the site was started in June 1946, and the station was brought into commission in August 1950.

The River Diversion*

A troublesome but technically interesting problem arose in connection with the control of the river during the construction. Originally it was proposed to cofferdam the river in halves, but unexpected difficulties with the river bed made it evident that the construction schedule could not be maintained on this basis, and the method was abandoned in favour of cutting a diversion channel across the tongue of rock enclosed by the river bend. By this means the loss of a season's work was avoided.

The site plan, Fig. 2, shows the system of cofferdams as originally proposed and as rearranged and actually constructed when the diversion channel was decided upon. It was intended first to enclose the site of the spillway by cofferdams *ABCDE* and *FG*, the former being subsequently extended to *RSJBC XYE* to take advantage of a better foundation at *S* and to accommodate a larger stilling pool, which model tests had shown to be desirable. The sluices were to have a finished sill level of 121 ft. O.D., but one was to be brought up to 107 ft. O.D. and the other two to 100 ft. O.D. so as to pass the river discharge when the cofferdams were breached. Final location for the power-station cofferdams were chosen at *TSJDE* and *LK*.

In order to leave the maximum width of river available for discharge a narrow cofferdam was desirable, and a concrete construction was decided upon, forming a wall 5 or 6 ft. wide anchored to the river bed by 1 in. twist steel reinforcing bars. It was assumed that sound rock would be found within one foot of the existing river bed.

The total length of the sluices cofferdam, *RSJBC XYE*, was 680 ft., and it was estimated that 340 ft.

* For a full account see a paper "River Diversions on the Erne Power Development—Part I. Cliff" read by P. A. O'Connor, B.E., on December 5, 1949, before the Institution of Civil Engineers of Ireland. Fig. 2 is reproduced from this paper.

could be built either in the dry or in a depth of water not exceeding 6 ft. By September 1946 a length of 180 ft. of this 340 ft. had been built at *E*, *R* and *S* without undue difficulty. For those portions of the cofferdam where the depth and velocity of the water were too great for normal methods to be used it was decided to employ a pontoon unit which had been designed to construct the cofferdam for the tailrace at Cathaleen's Falls. The purpose of this unit was to sink a caisson of sheet-steel piles, 23 ft. in diameter, within which a block 17 ft. 6 in. long was to be built up. Seeing that a continuous cofferdam could not be constructed by this method the 3 ft. 6 in. gaps between adjacent blocks were to be closed by 9 in. × 3½ in. precast planks entering 4 in. × 3 in. grooves in the end of each block.

This pontoon unit became available at the end of August 1946 and was placed in position at *Y*, but when the piles were driven to refusal they entered the bed to depths ranging from two to six feet. This was considerably greater than expected, and 5 ft. extensions had to be welded to the piles. An excessive depth of clay, soft rock and boulders increased the difficulty of dewatering, because even though the piles were driven to refusal, water still entered under the toes of the piles. In many cases piles struck large boulders and could be driven no further. A diver was constantly at work removing loose boulders from below the piles and sealing leakages with sandbags, and a bitumen compound had to be used to effect the seal between the piles and the river bed. In many cases adjacent piles had to be held together with steel wedges where they had been forced out of plumb. The actual dewatering operation took from four to five days.

After dewatering, scoured and fissured rock was removed to a depth of 3 ft., leaving a foundation of soft decomposed rock with pockets of boulder clay. Drilling revealed that conditions were similar for a further five or six feet, but it was not feasible to continue excavation owing to the inadequate length of piles available and the risk of a blow-through below the piles. A concrete sill was therefore laid on this foundation to provide a start-up lift for the shuttering and facilitate drilling, but efforts to grout in the reinforcement were unsuccessful because water was flowing out of the holes.

On account of these exceptional difficulties, only two blocks had been built by the end of November, occupying 34 and 21 days respectively to construct, and because of the weakness and permeability of the foundation their structural value was questionable. In the light of this it appeared very doubtful whether a satisfactory cofferdam could be completed by the following summer, in which event a year in the construction programme would be lost. On the other hand a diversion channel was seen to offer the possibility of dewatering the whole of the sluices and power-station site by June 1947, gaining a year on the programme.

The location decided upon for the diversion channel, which was 50 ft. wide, is shown in Fig. 2, the

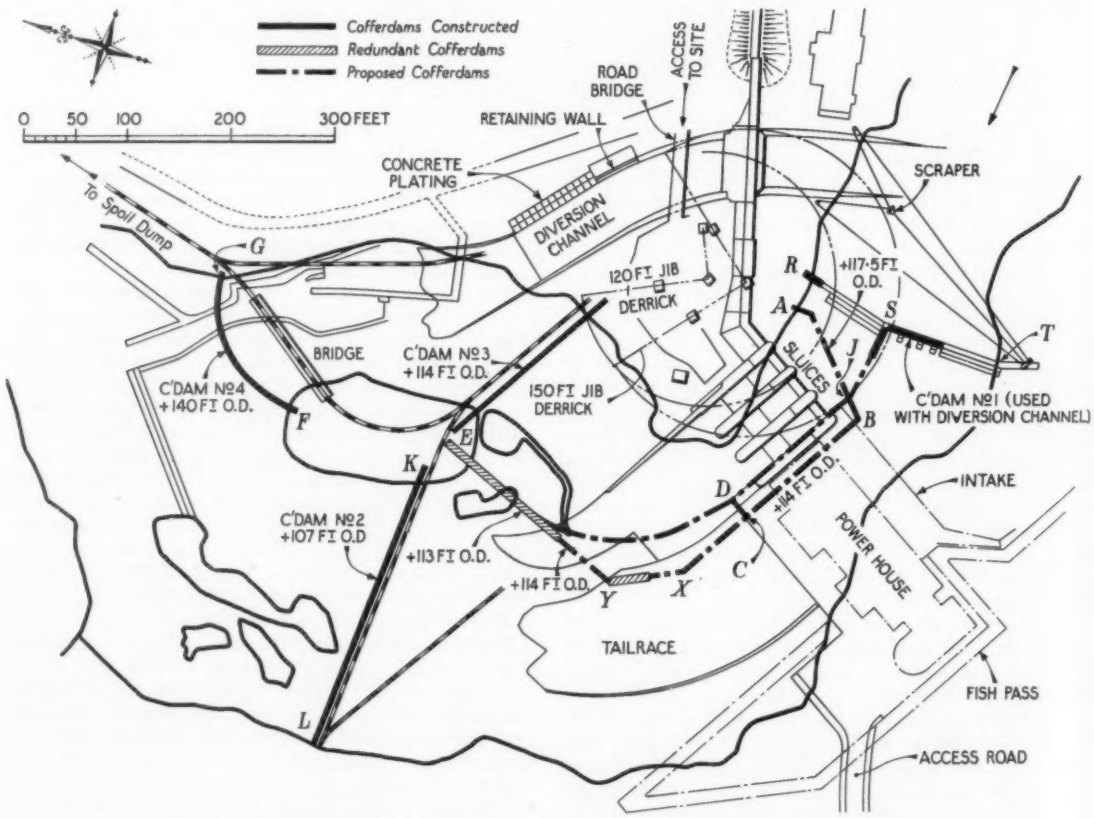


Fig. 2. Site plan showing the procedure adopted to divert the river

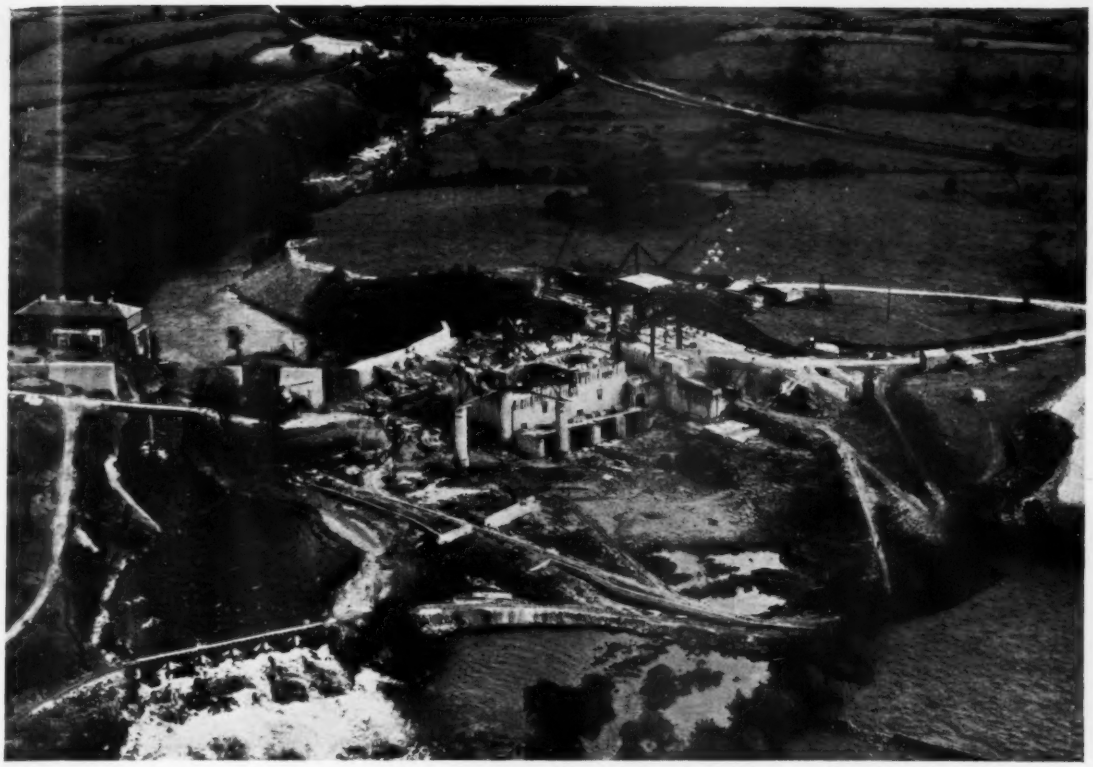


Fig. 3. Aerial view showing the river diversion

associated cofferdams being indicated at 1-4. Cofferdam No. 1 was in reinforced concrete, the others being formed of mixed rock and earth filling. This change in procedure necessitated an increase of 50 ft. in the length of the gravity section of the north wing of the dam, and to facilitate the closing of the channel when it was time to complete this section, abutments for an arch cofferdam consisting of precast beams were built on either side of the channel immediately upstream of the dam. For economy, these

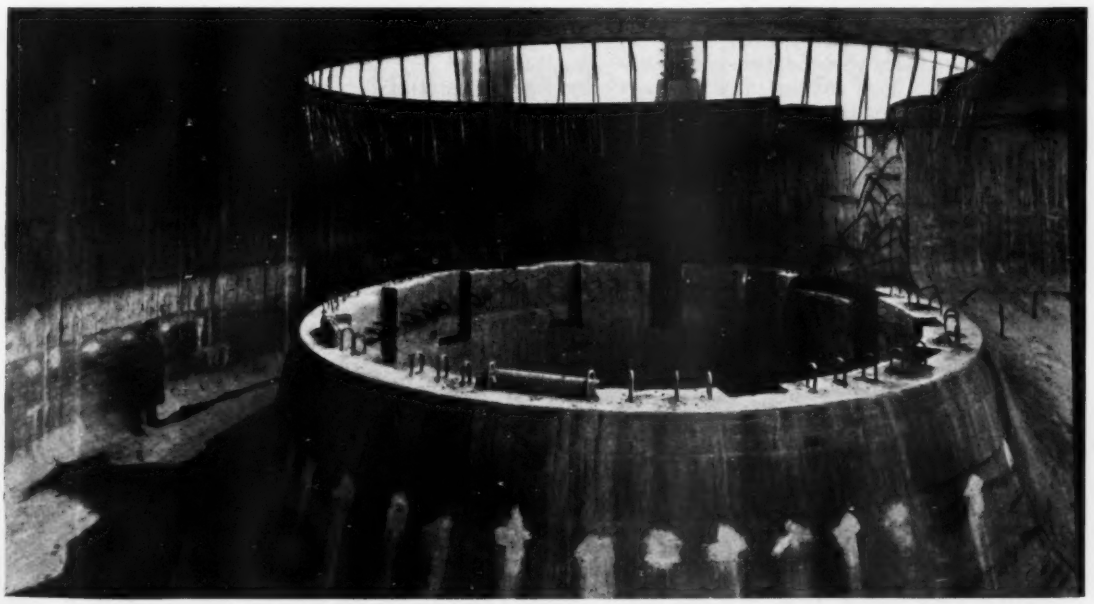


Fig. 4. One of the concrete spirals before installation of the turbine

abutments were combined with the vertical cut-off trenches of the dam.

The excavation for the diversion channel consisted of 18,400 cu. yards of rock and 6,900 cu. yards of earth, and was taken out in two benches, the first to 15 ft. O.D., and the second to an invert level, at the upstream end, of 101 ft. O.D. Work was begun at the junction of the north gravity wing and the diversion channel, progressing upstream, and for the first fortnight the rock was hand-loaded into 1¼ cu. yard hoppits and dumped by 120 ft. derrick into side-tipping skips. Once the temporary works were completed, excavation proper began on the first bench with a 17 R.B. face shovel.

Ingersoll-Rand and DA35 drifters on FM2 wagon drill mountings, and JA45 jack-hammers were used for drilling blast holes, which were loaded with a total charge ranging from 200 to 300 lb. of Polar ammon gelignite. The ratio of explosive to rock averaged 1 lb. to 1·7 cu. yard, but when blasting the upstream plug the ratio was 1 lb. to 1 cu. yard.

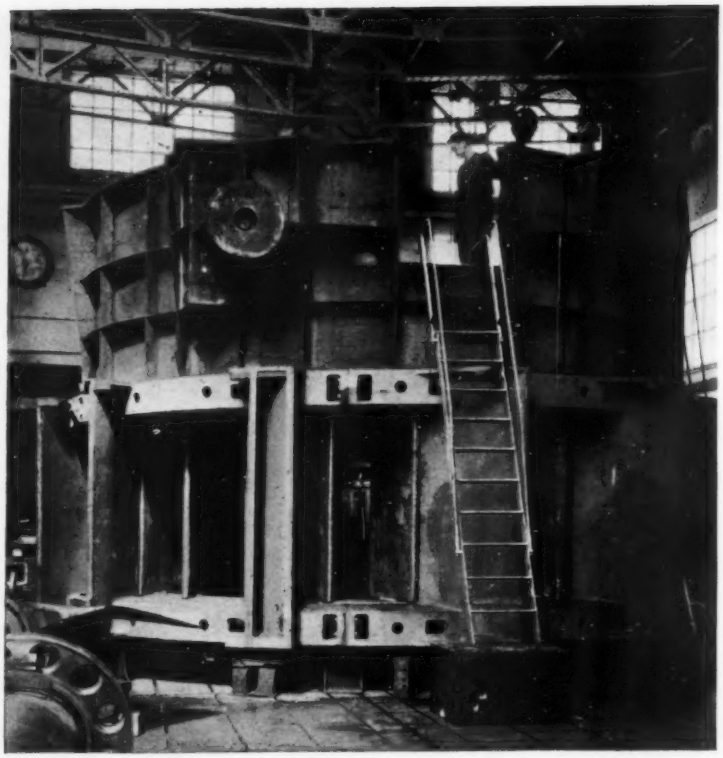


Fig. 5. The first 14,250 h.p. Charmilles turbine in the makers' works

The side slopes, where in clay, were covered with a 4 in. thickness of 8 : 1 concrete with a 2 ft. × 1 ft. vertical toe wall founded on rock. Where the sides were in soft rock they were gunited to a depth of 1½ in. by a 3 : 1 mix of sand and cement. Upstream of the abutments for the arch cofferdam already referred to, a 1 ft. thick concrete lining wall was constructed, tied to the rock with reinforcement.

On June 10, 1947, cofferdam No. 4 was removed by 17 R.B. dragline, allowing the downstream area of the channel to flood. At the same time a 35 h.p. electric scraper removed loose material from the river bed upstream of the plug, and all clay and loose rock were removed by hand from the plug itself. The plug was blasted in three stages and the spoil drawn to the left-hand side of the river by drag scraper.

Meanwhile work had been proceeding on cofferdam *RST*, which was constructed as a gravity section because the weakness of the foundation made it impossible to drill and grout reinforcement, and there remained a gap of 57 ft. between *R* and *S* to close. The spoil was therefore scraped across to form a dam upstream of this gap to enable it to be closed. After the closure some trouble was experienced with a burst, but this was finally sealed off and the site pumped dry.

From the beginning of the activities on the site, work had been proceeding on the excavation of the south bank for the power station. Drilling of the rock here, as on all parts of the site, was difficult because the holes filled with small pieces of rock, and the best results in drilling and excavation were obtained by quarrying the face in 10 ft. benches. Due to the narrowness of the face and the difficulty of access, the spoil at first had to be loaded by hand into trains of four 1 cu. yard side-tipping skips drawn by 25 h.p. diesel locomotives, and it was not until the excavation was half completed that it was possible to work round the clock and have four rakes of skips available for loading in the 60 ft. width.

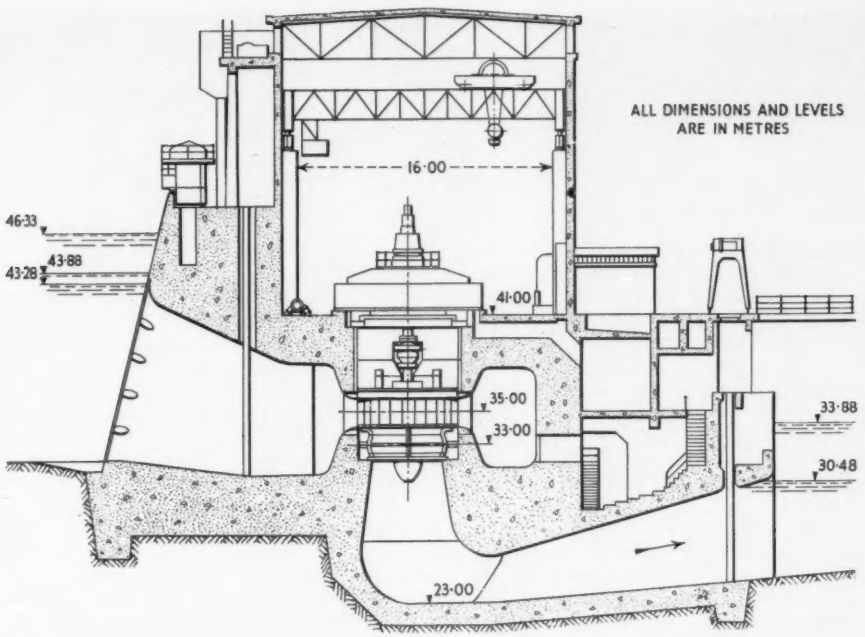
When the river bed had been dewatered, a 15 ft. deep channel was disclosed containing decomposed rock and clay similar to that found under cofferdam *ST*. Excavation of the dam site then proceeded by ⅝ cu. yard power shovels.

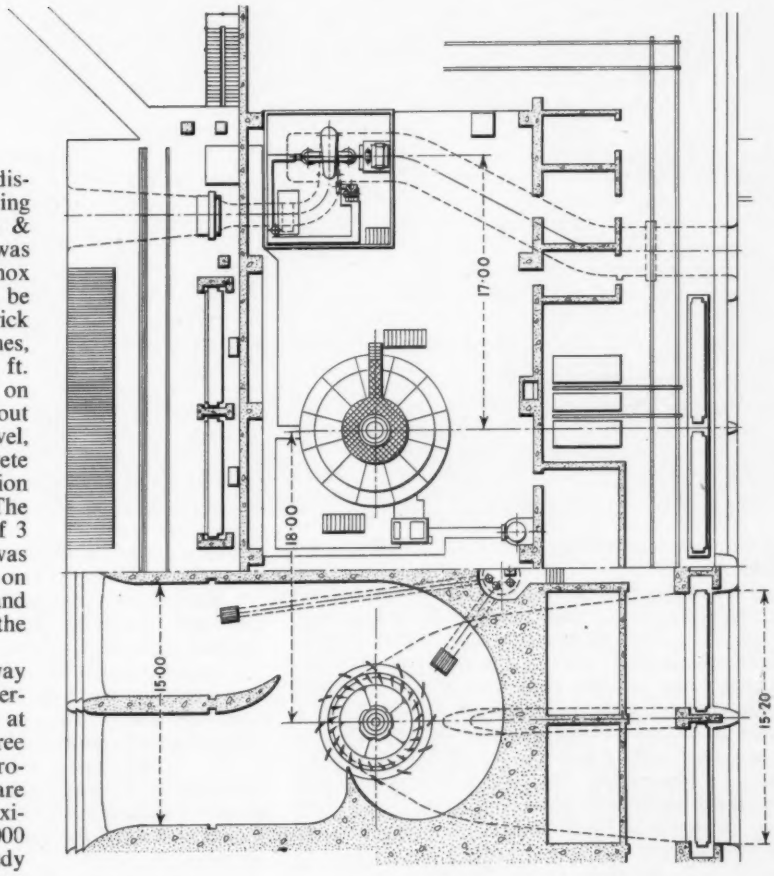
Grouting

A deep cut-off curtain was grouted in under the core trench throughout its length. The usual practice was to drill and grout in stages to refusal at the pressure appropriate for the particular stage, deep grouting in primary and secondary holes being done before any concrete was placed. The first stage, down to 15 or 25 ft., was blinded with 1:1 mix by volume, the second stage to 40 ft. was grouted at 60 lb. per sq. in., the third stage to 60 ft. at 100 lb. per sq. in. and stages below 60 ft. at 125 lb. per sq. in. In cases where deep holes took large quantities of grout, half of the cement in the 1:1 mix was replaced by stone dust. Junction and first-stage grouting was effected after at least 16 ft. of concrete had been placed. Final test grouting was carried out from the upstream face of the dam down through the core trench into the deep grout curtain.

Dam and Spillway

Concrete for the dam was brought by 4 cu. yard side-tipping trucks from the central mixing plant at





Cathaleen's Falls and discharged into a hopper feeding a 2½ cu. yard Ransomes & Rapier remixer. Thence it was transported by Blaw-Knox bottom-dumping skips to be handled on the site by derrick cranes. One of these cranes, accepting 3 tons at 145 ft. radius, was mounted on hollow concrete pillars about 50 ft. above excavation level, and handled all the concrete in the intake, power-station foundations, and sluices. The other, having a capacity of 3 tons at 115 ft. radius, was first employed for work on the right bank of the river and was later transferred to the left bank.

The design of the spillway and stilling pool was determined by model tests at Trinity College, Dublin. Three 20 ft. wide sluices are provided, any two of which are capable of handling the maximum known flood of 11,000 cusecs. Glenfield & Kennedy double gates control these sluices. The bottom leaf of each gate is of the free-roller

Fig. 6. General layout drawings of Cliff power station

type, is 21 ft. high, has a lift of 26 ft. 6 in., and weighs 19 tons; the top leaf is of the fixed-roller type, is 10 ft. 8 in. high, weighs 8·6 tons, and has an effective height over the top of the lower leaf of 10 ft. All gates are electrically operated and are controlled by pushbutton from the generator floor, with duplicate pushbuttons on the gate gantry. Six dam beams, 5 ft. 3 in. high, are provided to enable any one sluice to be shut off.

Salmon and Elver Passes

The salmon pass is of the orifice type as developed by the North of Scotland Hydro-Electric Board and already described in this journal.* There are 36 pools, each 24 ft. long, 12 ft. wide, and 7 ft. deep, with a 1 ft. 6 in. rise between pools and a 2 ft. 3 in. diameter submerged pipe orifice 5 ft. long. To ensure that the flow through the pass is kept constant regardless of the reservoir water level the three uppermost pools are provided with automatic gates; the gate appropriate for the water level obtaining is opened by an Evershed & Vignoles "No-flote" control, the other gates being closed. There is also a smolt chamber provided with an automatic gate the sill of which is kept at a constant depth below the water surface.

The elver pass consists basically of a sloping concrete trough rising at a slope of not more than 1 in 4 from the lowest tailrace water level to an elver chamber built into the upstream face of the dam. This trough is filled with $1\frac{1}{2}$-$\frac{3}{4}$ in. broken stone, and water flows constantly down through the stone, the elvers travelling up through the interstices between the stones. At the upper end of the pass they enter a pivoted hollow arm the upper end of which is attached to an open-ended rectangular box carried on floats so that its lower edge is maintained just at water level. Straw and hemp ropes are laid within the lower side of this hollow arm, and are kept wet by the film of water flowing from the box and on down the pass. The elvers travel up these ropes and into the elver chamber, in which this arrangement is housed, and pass out to the reservoir through a slot in the face of the dam.

Intakes, Spirals and Draught Tubes

Each turbine will utilise a maximum flow of 4,200 cusecs, and is provided with twin intakes and draught tubes. Each pair of intakes is protected by a screen consisting of 3 in. by $\frac{3}{8}$ in. steel bars set on edge at $2\frac{3}{8}$ in. centres, the upstream edges of the bars being circular. Electrically operated trash rakes are available.

Two Glenfield & Kennedy free-roller intake gates are provided for each turbine, each 22 ft. $11\frac{1}{2}$ in. wide by 27 ft. 2 in. high. Seeing that the turbine makers have provided a safety high-pressure oil system, which shuts down the turbine on failure of the ordinary high-pressure oil system, it has not been necessary to make these gates of the automatic-drop type, and they are used only for emptying the spiral for inspection of the runner. They are therefore arranged to be raised electrically at a rate of 18 in. per min. and to be lowered by gravity on a hand brake, a centrifugal brake coming into action at a lowering speed of 3 ft. per min. should the hand brake fail. The total closing time is about 5 minutes.

A single intake suffices for the house set, and is closed by an 8 ft. by 8 ft. Ransomes & Rapier stop gate.

The concrete spirals at Cliff, which have a maximum radius of 27 ft. $2\frac{1}{4}$ in., are stated to be the first to have been constructed in the British Isles and to be the largest. The shuttering was designed by C. Parry, as was that for both the Cliff and the Cathaleen's Falls dams.

The draught tubes were finished smooth without the use of plaster, and each pair of tubes presents an outlet area of 1,750 sq. ft. One pair of dam beams is provided for the two turbines, handled by a portal crane travelling on rails on the tailrace platform.

Spiral casings and draught tubes are drained through pipes and valves terminating in a sump, located between the two turbines, which also collects station seepage. Two vertical borehole pumps serve to drain thus sump. The larger, a 2,000 g.p.m. manually controlled pump, dewaters the spiral casings and draught tubes, whereas the smaller, of 200 g.p.m. capacity, deals with seepage and is float controlled.

Turbine

As stated in our previous article, one 10 MW set is in commission at present, but the second set, which will be identical, is on order.

The turbine is of the Kaplan type and was built by Charmilles Engineering Works Limited, Geneva. It develops 14,250 h.p. at 115·3 r.p.m. at the rated head of 10 m. (32·8 ft.) and at 87·8 per cent. efficiency, but is designed to function at all heads ranging from 8 and 15·85 m. (26·3 and 52 ft.), the normal maximum head being 14·10 m. (46·5 ft.).

A view of the turbine assembled in the makers' works appears in Fig. 5. The stay ring is of cast iron, with integral vanes, and takes the weight of the generator and rotating parts through a pit liner on which the generator is seated. The guide vanes are of cast steel moving in bronze-lined bearings. Breaking pins are used in preference to breaking links, and shims in the connections from the regulating ring enable the setting of each vane to be adjusted independently. A spring-loaded bolt is provided to lock the ring in the closed position.

The cover plate is of box section, and is fitted with a central cover to allow the runner to be withdrawn without disturbing either the runner blades or the guide apparatus. This central cover carries a connecting piece reaching down to the runner hub and containing the main guide bearing, the water gland, the air valves, and a housing containing the governor pumps and overspeed safety devices.

Lubrication of the guide-vane mechanism and of the turbine guide bearing is effected by grease nipples grouped near the footbridge at regulator-ring level.

The runner chamber and throat ring are of stainless steel, and the upper part of the draught tube is lined with steel plate.

Five stainless-steel blades are provided on the runner, which has a cast-steel hub. All the blade mechanism is contained within the hub, and is drowned in heavy oil; it is operated by a servomotor located between the turbine and generator coupling flanges.

The governing and control equipment is centred in a cabinet, depicted in Fig. 8, on which are mounted all the controls and indicating instruments necessary

* "Pitlochry" WATER POWER, May 1951, page 164.

Fig. 7. The Brown-Boveri 10,000 kW 10,500 V alternator coupled to the Charmilles Kaplan-type turbine

for starting, stopping and regulating the speed of the turbine. Governing is on the speed-acceleration principle, the governor pendulum being electrically driven from a three-phase tapping taken off the pilot exciter. When the set is to be started, the field of this exciter is supplied from a battery, which is automatically switched out as soon as the machine is running and self-excited.

The combinator mechanism is also housed in this cabinet, and to enable the turbine to operate efficiently over the wide range of head to which it may be subjected, three cams are provided to suit successive head ranges. Any cam can be brought into use by turning a knob.

Oil for the governing system is normally supplied by one of the gear pumps driven from the turbine shaft, and is duplicated by a motor-driven screw pump which is used for starting and also comes into service automatically should the oil pressure fail. These pumps supply oil pressure to the air vessel, seen in the background in Fig. 8, and operate in conjunction with an unloader valve, causing the pumps to run light when the pressure in the air vessel reaches the normal operating pressure of the oil. As an overriding safety control a second gear pump, operating at high pressure, is driven from the turbine shaft, and is brought into action by the overspeed trip. This trip also disconnects the guide-vane and runner servomotors from the normal oil system and connects them to the emergency gear pump, ensuring that the turbine is shut

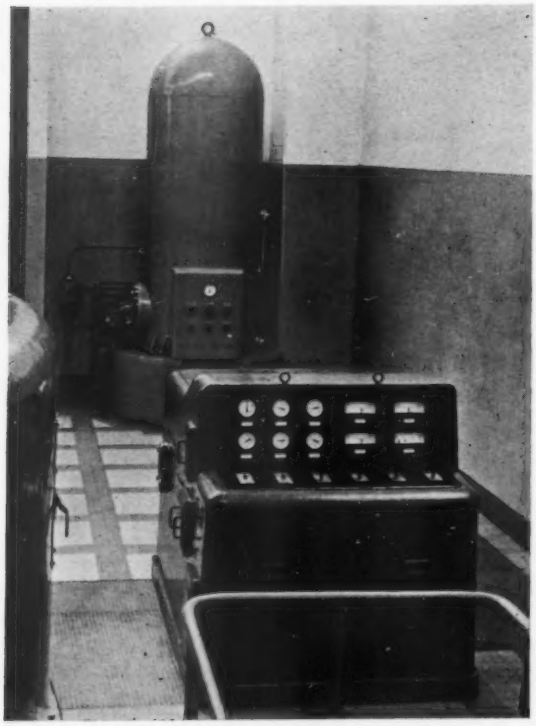


Fig. 8. Turbine governing and control cabinet, with pressure-oil equipment in the background

down even in the event of a complete breakdown of the governor and oil pressure system.

Alternator

The alternator is of Brown-Boveri manufacture, and is rated to generate 10,000 kW at 10,500 V, 0·8 power factor, three phase, 50 cycles. It is designed for a runaway speed of 280 r.p.m. and has a flywheel effect of 13 million lb. ft.^{2}. The rotor is built up, with fabricated arms and a rotor rim made of sheet-steel segments pressed together by bolted screws, the poles being fixed to the rotor rim by screws.

Except for the lower guide-bearing bracket the machine is above generator floor level, and is surmounted by a 95 kW 220 V main exciter and a pilot exciter supplying 5·5 kW d.c. and 2·5 kVA three-phase a.c. for the governor.

The thrust bearing is sunk into the upper guide-bearing bracket and is of the segment type, designed for a total load of 365 tons. It is drowned in oil, and the two guide bearings are also self-lubricating. Water cooling is applied to the upper guide bearing and to the thrust bearing, the cooling coils being placed in the bearing shelves in the former case and in the oil reservoir in the latter. The lower guide bearing is air cooled.

The stator winding has two bars per slot, the conductors in the bars being divided into single layers transposed inside the length of the slot to minimise losses.

Cooling is on closed circuit by means of six coolers mounted around the stator frame. Cooling water for all purposes is drawn from a tank in the station roof.

House Set

Power for auxiliaries is derived from a Charmilles/Brown-Boveri house set comprising a 440 h.p. 500 r.p.m. double-flow horizontal Francis turbine direct coupled to a 300 kW three-phase alternator supplying a double-busbar station system at 380 V. This system is interconnected with the house supply at Cathaleen's Falls by duplicate 10 kV overhead lines with 0·5 MVA transformers at either end.

Main Electrical System

The generator terminals are connected to a minimum-oil contraction type circuit breaker with a motor-wound spring-operated opening mechanism, the breaker being rated to carry 1,000 A and having a symmetrical breaking capacity of 20,000 A. From this breaker the power is taken to a 10/110 kV transformer mounted on the tailrace platform, and provided with 14-step on-load tap-changing gear; it is naturally cooled up to about 60 per cent. load, above which cooling fans come into operation. The power is taken by overhead line to the outdoor switching station at Cathaleen's Falls, where it is fed to one or other of the two bars of a double busbar system.

As mentioned in our previous article, Cliff power station is operated under the directions of Cathaleen's Falls, but starting, stopping and synchronising are carried out locally. As the control operations required at Cliff are consequently limited, it has been unnecessary to provide a separate control room, and the

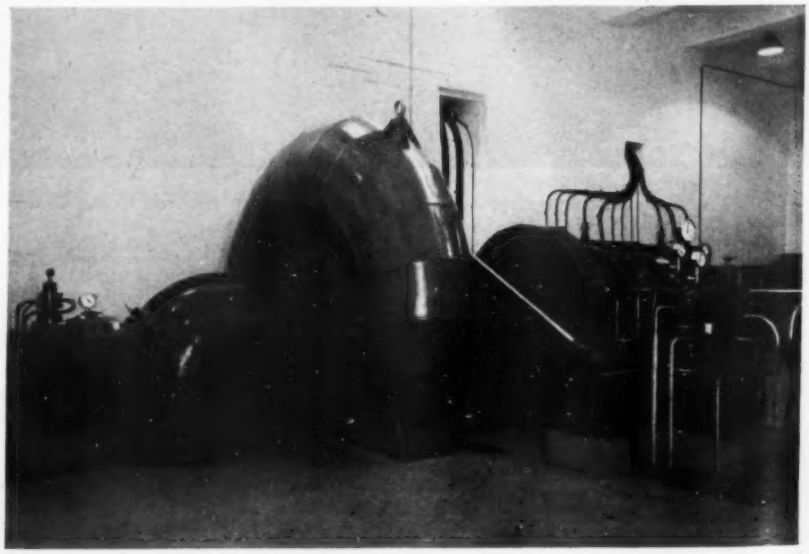


Fig. 9. Charmilles/Brown-Boveri 440 h.p. 300 kW house set

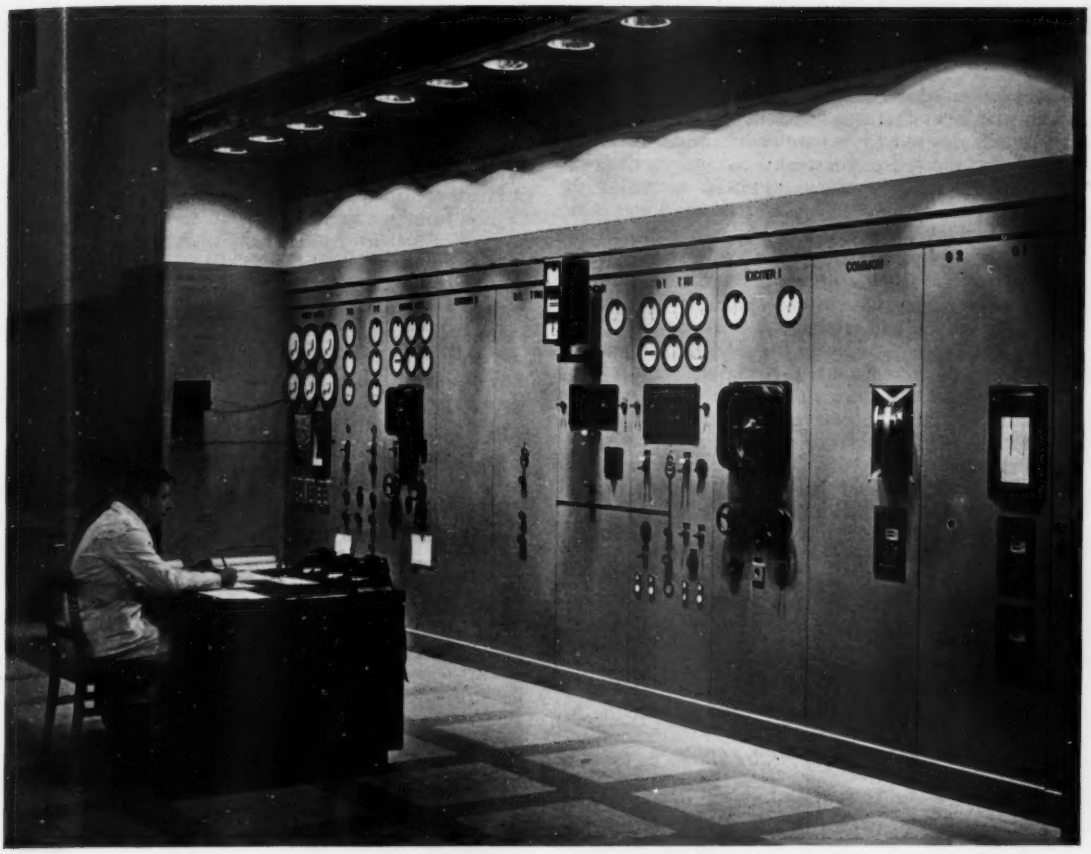


Fig. 10. The Cliff control board. This board forms part of the wall of the generator hall and is operated under instructions from Cathaleen's Falls

control board (Fig. 10) is located in the generator room. On the extreme left of this board is a panel carrying the pushbuttons and indicators for the spillway crest gates. Then follow panels for the house-service transformers and house set, for the main generators and their exciters, synchronising, and metering. Brown-Boveri voltage regulators are mounted on the board for both main and house sets.

All synchronising is carried out at generator voltage, and elaborate facilities, including automatic synchronising, have been provided in both stations to ensure quick and foolproof operation. A synchronising bracket in the centre of the control board carries a synchroscope, a double frequency meter and a difference voltmeter, and by the side of the control switch for the generator breaker is a small changeover switch with a removable key, which may be turned to either "hand" or "automatic," automatically selecting the voltages of the two systems to be paralleled and connecting them to the synchroscope. This selecting operation is complicated by the fact that there are no voltage transformers directly connected to the 110 kV busbars at the outdoor switching station, and recourse has to be made to one of the combined current and voltage transformers associated with apparatus connected to the busbar concerned. To effect this, when the appropriate isolator has been closed, a system of relays automatically locates a current and voltage transformer connected to the selected busbar. Synchronising then proceeds by hand or automatically as the case may be.

Protective relays are mounted on the back of the control board, and cover stator earth fault, overcurrent, differential, overvoltage, reverse power, and rotor earth fault. A number of electrical circuits are also used for the protection of the turbine. All faults, both tripping and non-tripping, are signalled on indicating panels mounted on the control board, and appropriate audible warning is also given.

Direct current for relay and control circuits and for telephones is derived from 220 V and 24 V batteries.

All the transformers, circuit breakers, switch and control gear and cables were supplied by Allmänna Svenska Elektriska AB., Sweden, or their associated company, ASEA Electric Limited.

Cliff station is provided with a 45 line automatic telephone exchange and is interconnected with the exchange at Cathaleen's Falls. In addition a magneto phone is connected over a 50 pair pilot cable between the two stations.

NOTE. This series on the Erne River development will be concluded by a description of Cathaleen's Falls station, to appear in two instalments in our September and October issues.

Slide Rule for Penstock Calculations

One of our readers, who is an expert in penstock design and manufacture, has sent us a pocket slide rule he has devised by means of which many of the basic calculations for penstocks can be carried out very simply. It is in every respect a normal 6 in. (15 mm.) slide rule but has additional markings. One of these enables the rule to be set to accord with the relationship between pipe diameter, water velocity, and discharge, so that if any two of these quantities are known the third can be read off directly. A second marking gives a direct reading of the weight of a steel pipe per millimetre thickness for any given diameter. Metric units are employed throughout.

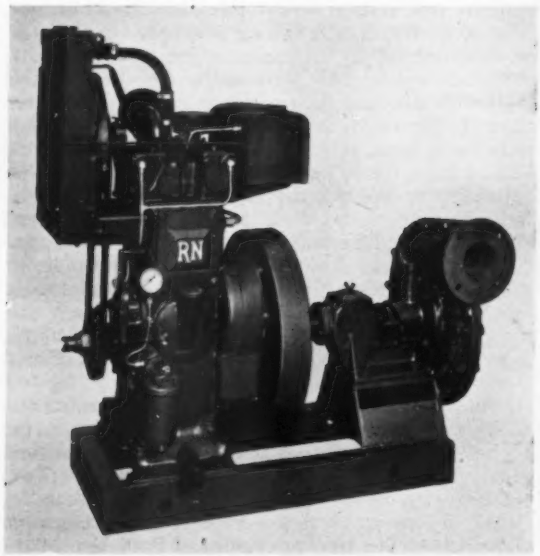
Another useful feature is that the centre slide is made longer than the rule itself, a point that adds considerably to convenience of handling.

Altogether the instrument impresses us as a handy little tool which should be of real convenience in carrying out these special calculations without in any way interfering with its utility as a normal engineer's pocket slide rule.

The designer will be pleased to send one of his rules without charge to any *bona fide* hydraulic engineers who care to apply through the editor of this journal.

New 5-8 b.h.p. Diesel Engine

A small single-cylinder diesel engine suitable for all kinds of small-power applications in remote localities has been placed on the market by Russell Newbery & Co. Ltd., Dagenham, Essex, after four years of intensive development. During this time a number of prototypes have been built, two engines have been subjected to extended service in India, and one engine has run over 400 million revolutions. The "Husky" engine, as it is called, develops from 5 b.h.p. at 1,000 r.p.m. to 8 b.h.p. at 1,500 r.p.m., and weighs 500 lb.



Russell Newbery "Husky" engine driving a pump

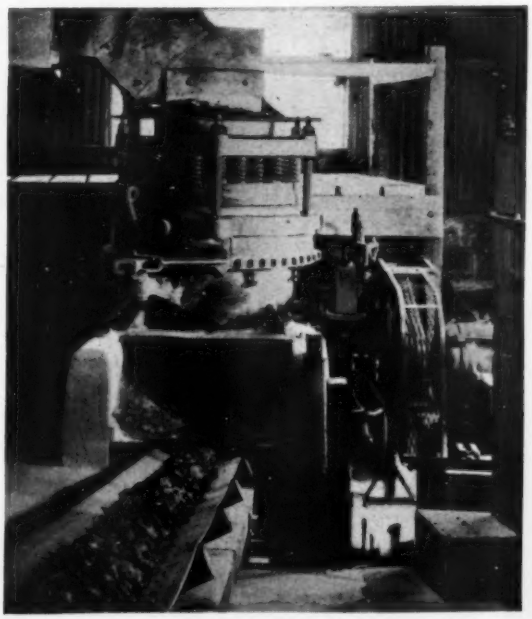
A half-speed take-off shaft can be fitted if desired.

An inspection of the engine shows that the usual claim of "robust construction" can be fully substantiated in this case, for it has obviously been designed with an eye to trouble-free service in rough conditions in any part of the world. It is totally enclosed, all screwthreads conform to the "unified" system, essential maintenance can be carried out with the minimum of stripping down, and the use of a comet-type combustion head gives an engine with comfortable running properties and a catholic taste in fuel.

Manufacturers and users of contractors' plant should find this engine a convenient self-contained power unit; it is suitable for driving small pumps, welding or other generators, or small field workshops; and those of our readers who are concerned with irrigation may like to know that its use for driving local irrigation pumps is an application that has been kept well in mind by the designers.

An Aggregate-Crushing Problem

The reduction of materials suitable for making concrete aggregate is a routine job presenting few difficulties, but in the case of John W. Swindells Ltd., New Mills, Derbyshire, it presented many problems which arose principally from the fact that their aggregate is produced from rock containing an exceptionally high silica content—91 per cent. The abrasive action of such material is obvious and the resultant wear and tear on the crushing plant was severe, in fact it proved necessary to turn the crusher jaws every two months and renew them every six to seven months. Quite apart from the cost of replacement the expenses arising from idle machine time, labour and the disruption of production proved very costly.



Pegson "Gyrasphere" crusher at Swindells Derbyshire works

The problem was solved by the installation of a

Pegson 24 in. Gyrasphere crusher. Although it has been working for over 18 months and has crushed 15,000 tons of aggregate the same concave and mantle have been used throughout, and have only just been replaced after a recent overhaul. In addition, there has been a sharp reduction in undesirable fines which have fallen by over 50 per cent.

The Pegson 24 in. Gyrasphere crusher is constructed on the principle of an inverted pestle and mortar. There is large feed opening and the design permits unobstructed and unlimited feed. This principle enables the maximum number of crushing blows to be made at high speed before discharge, and wear and tear on the manganese crushing faces is said to be greatly reduced. The product is of cubical shape and the dust is reduced to negligible proportions.

New Rust Inhibitor

Our attention has been drawn to a new rust inhibitor produced by Cowanite (Anti-Corrosive) Limited, 15, Tithebarn Street, Liverpool 2. It is a solution comprising pure zinc, carbon, and rubber latex, and can be applied either by brush or by spray. Preliminary sandblasting, scraping or chemical cleaning is unnecessary as Cowanite can be applied over rust, mill scale or old paint provided that all loose particles are removed. It is touch dry in 14 minutes and hard in 40 minutes. It can be used as a finish or as a primer for synthetic or oil-bound paints. It is also advocated as a protective for non-ferrous metals, a waterproof surface for concrete, cement and stone, and a repellent to dry rot and fungus in timber.

Abstracts from the World Technical Press

Lessons from a Burst Penstock

On November 15, 1952, the Doron de Champagny penstock feeding the Bozel-Maletra power station burst after 40 years' service. This penstock operated under a gross head of 550 m., it was about 1,300 m. long and was in three sections having diameters of 950, 850 and 800 mm. respectively. The upper 300 m. run was of riveted construction having plate thicknesses ranging from 6 to 15 mm., the remainder consisting of plates ranging from 12 to 30 mm. thick welded by water gas. The burst occurred in the region of the junction between the riveted and the welded sections, and appears to have commenced at a longitudinal weld, extending 1·6 m. up the pipe to meet the riveted sleeve forming the junction (see Fig. 1).

Unfortunately the automatic shut-off valve at the head of the penstock failed to close, with the result that for two hours the water flooded the track of the adjacent Pralognan conduits, comprising a plain welded discharge pipe and a pressure penstock having an upper section of plain welded pipes, a central section of cable-reinforced pipes and a lower section of self-hooped pipes with rigid hoops, all pipes having been subjected to the over-pressuring technique developed by the author. These conduits were installed in 1947-48 and were buried, but over a length of 180 m. in the region of the pipes with rigid hoops,

Fig. 1. The burst in the Champagny penstock

Fig. 2. Scouring at No. 11 anchor block

the earth filling was completely washed away, leaving a trench up to 10 m. deep below the pipes. Concrete supports were demolished, and three anchor blocks were exposed, the centre block being undermined and subsiding 20 cm., carrying the pipes with it (see Fig. 2).

The pressure penstock was in service at the time, and the station attendant, noticing that something was abnormal, shut down the generating sets but left the penstock under pressure for two hours. Even so, apart from a leak at the bolted joints where a cast-steel section carrying a manhole was inserted in the pipeline, the penstock remained watertight, and after it had been jacked back to its original position and placed on temporary supports it continued to function without mishap.

Before 1910 it was the practice in France to construct penstocks by riveting, and before 1907 the rivet holes were punched, with disastrous effects on the metallic structure of the plates. This kind of trouble disappeared when the holes were drilled and reamed.

In 1910 water-gas welding was adopted, but no means were available of detecting any faults in the welding, which was found to induce brittleness, and in 1930 it was superseded by electric welding.

The hydraulic test is the most reliable method of controlling the manufacture of welded pipes. Originally in France this was fixed at 1·5 times the working pressure—often taken as the static pressure—but numerous factors in service led to a reassessment of the position in 1918, when it was laid down that (1) the working pressure should be taken as the static pressure plus the maximum surge pressure occasioned by normal operation of the pump or turbine, (2) the factor of safety should be 2·5 with respect to the elastic limit, (3) a hydraulic test should be imposed of twice the working pressure as defined in (1) above. No service failure has occurred on any penstock built in accordance with these regulations.

The following observations were made on the Champagny fracture: (1) The rupture was not along the line of the weld but along the edge of the fusion zone. (2) There was neither crack nor slag inclusion, but the appearance was that of a brittleness fracture. (3) The pulsating stress to which the penstock was subjected was not severe enough to induce a change in metallic structure, and it was concluded that a hydraulic test to twice the working pressure would have disclosed the weakness during manufacture. (4) On subsequent tests the permanent elongation of the metal was only 0·16 per cent. at the elastic limit as against the specified figure of 0·2 per cent.

Since the author's firm adopted electric welding, together with over-pressured and self-hooped construction, no service failure has been recorded, and the following conclusions have been established: (1) No self-hooped pipe has ruptured on test below the elastic limit. (2) The very few ruptures beyond the elastic limit have occurred in welds shown to be faultless by radiographic methods, and appear to be due to brittleness which can only be discovered by a test beyond the elastic limit. (3) Even beyond the elastic limit no premature fracture has occurred, even where considerable plastic deformation has taken place.

The author also considers that the experience with the Pralognan penstock has demonstrated the soundness of the "French" method of constructing penstocks without expansion joints. (G. Ferrand, *La Houille Blanche*, No. 1, 1953, p. 20, 8 pp., 8 ff.)

Missouri Basin

The Missouri Basin Inter-agency Committee, meeting at Torrington, Wyoming, a few weeks ago, formulated a conciliatory position on the high v. low dam controversy which has centered particularly on the Oahe dam near Pierre, South Dakota, the largest Missouri River main-stream dam to be built under the Pick-Sloan plan. The Committee's principal findings, which aim at smoothing down the differences between flood-control and water-use interests, were as follows:—

1. The Corps of Engineers' major dams, levees and channel improvements are essential to control and to help prevent destructive floods;

2. The Department of Agriculture's watershed programmes are essential for improving and protecting the land, reducing runoff and preventing flood destruction in any of the upper watersheds;

3. Neither is a substitute for the other in the overall basin development.

After stating that the watershed programmes will have only minor effects on catastrophic floods such as experienced in the Kansas and Missouri Valleys in 1951 and 1952, the Committee's report agreed that the Corps of Engineers' projects are necessary for the control of major floods downstream and that these improvements should be undertaken where soundly justified by economic and other considerations. *(Engineering News-Record*, Vol. 150, No. 14, April 2, 1953, p. 22, col. 3.) Note: See WATER POWER, June 1953, p. 200.

Toce Development, Italy

Two works are described which the Italian Edison Group is now completing for the purpose of increasing hydro-electric production in the Toce basin—the new Isorno-Vipata plant, and the extension of the Crego plant. Work on the former installation, which began towards the end of 1951, includes:—

(a) a dam on the Isorno torrent, 23 m. high, 64 m. long, creating a storage of 69,000 cu. m.;

(b) a diversion pressure tunnel, 3,470 m. in length, on the left bank of the Isorno between the reservoir and the power house, with two auxiliary intakes: one on the Rio Nocca, connecting with the reservoir by means of a gallery 530 m. in length, and the other on the Rio Gillino, a left-bank tributary of the Isorno;

(c) a steel penstock, laid partly in a tunnel, partly at the surface, about 690 m. long, 1,150 to 800 mm. in diameter;

(d) a power house with two 5,300 kW alternators driven by Pelton wheels, and an outdoor switchyard.

The diversion tunnel is designed for a discharge of 2·5 cu. m. per sec., the installed capacity of the power house corresponds, however, to a discharge of 3 cu. m. per sec. in order to ensure a reserve in case of repairs to one of the generating groups.

The Crego plant was built in 1919 before the setting up of the upstream seasonal reservoirs (six smaller reservoirs with an aggregate capacity of 58·5 million cu. m., and the new Sabbion reservoir of 33 million cu. m., now in course of construction), and had to be extended to cope with the increased supply of power water. The increase of frequency from 42 to 50 cycles also made a renovation of the powerhouse equipment necessary. These works comprise:—

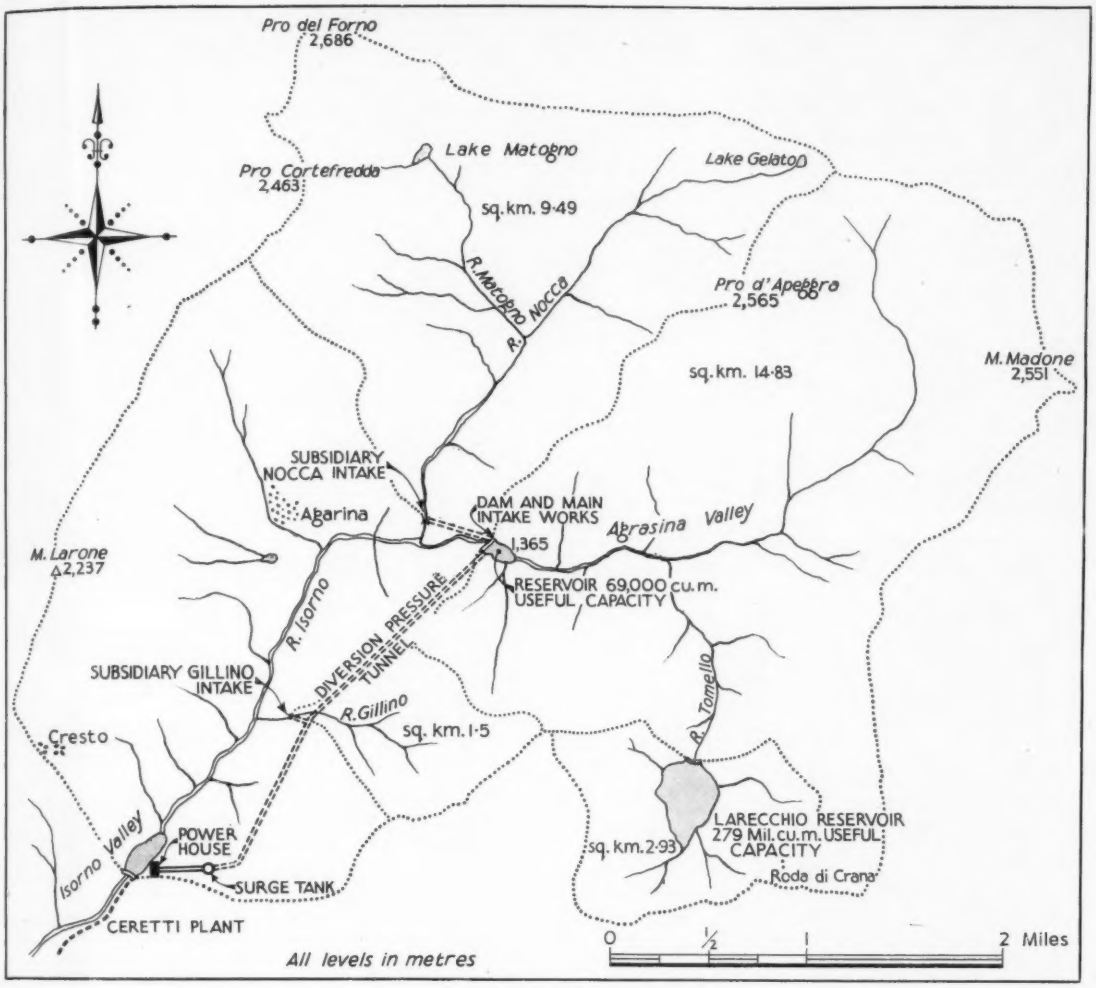


Fig. 1. Map of the Toce development

(1) increase of the overall storage capacity of the reservoirs to 108,000 cu. m. in order to obtain a greater concentration of the discharge;

(2) widening and correcting of the free-flow diversion canal to raise the discharge from 9·5 to 24 cu. m. per sec.

(3) raising the water level in the forebay by 0·9 m. so as to increase its useful capacity and ensure a higher operating head;

(4) substituting a single steel penstock with diameter tapering off from 2·5 to 2·2 m. for the three old 1 m. penstocks;

(5) replacing the three old horizontal generating sets by two new ones with vertical shaft, so as to increase the total capacity from 15,000 to 39,000 kW;

(6) setting up a new tailrace, 580 m. long, in part tunnel, in part open canal, in order to utilise the existing difference in level between the tailwater below the power house and the intake of the next downstream plant at Crevola; the maximum gain in head is about 3·5 m.

These extensions will increase production at the Crego plant from 90 million to 111·2 million kWh and, at the same time, bring about a substantial improvement in the quality of the energy supplied, since daytime production will increase by 40 million kWh, and night production decrease by 19 million kWh. This improvement will also benefit the upstream and downstream plants of the system. (*Quaderni di studi e notizie*, Vol. 9, No. 140, Feb. 1, 1953, p. 84, 3½ pp., 4 ff.)

Tidal Energy

The characteristics of tidal energy, the fluctuations of which are in correlation with the phases of the moon and the seasons, are reviewed, together with the forecasting of tides, the power available, and the daily, weekly and monthly variation of energy production.

According to computations made by the well-known hydrographer M. Allard, a spring tide dissipates, on the average, energy amounting to 157 million kW in the whole area of the Channel, of which no less than 24 million kW is in the section comprised between the north coast of Brittany and the west coast of the Cotentin peninsula, limited by a line connecting the Héaux de Bréhat with the head of the Cap de la

Hague, and passing through the Channel islands of Guernsey and Alderney. How far this production can be modified by a power-consuming installation is a widely complicated question to which only a very close analysis can supply the answer. As to the maximum production of a given plant, it will vary with the phases of the moon just as the level of the tide varies which generates it.

Weekly graphs accompanying this article show that the fluctuation of power remains below 15 per cent. of the average production; referred to longer periods, this fluctuation is considerably smaller and does not exceed an average of 3 per cent. in a period of 30 consecutive days. The great disadvantage of tidal energy is that it cannot submit to the timetable of normal life; it is however offset by the possibility of very accurate forecasting as well as by the fact that, on the average, it remains constant the whole year round and does not depend on the variation of hydrological conditions.

Tidal energy which cannot be adapted economically to the requirements of a single town or of a single branch of industry, will always be able to play an important part in the widely interconnected system in which it will harmonise with the other sources of energy; in spite of the fact that tidal energy can never guarantee any instantaneous supply of power, it will always prove a most valuable help during dry winters. (L. Vantroys, *Electricité*, Vol. 37, No. 191, February 1953, p. 25, 5 pp. 8 ff.)

Earthfill Dam Compacting by Pneumatic Rollers

Field tests of special types of pneumatic rollers conducted over the last five years in America have demonstrated to the satisfaction of soil experts of the Corps of Engineers that both time and money can be saved by the use of such rollers in the construction of rolled-fill dams. Using rollers built to the specifications developed by the Corps as a result of these extensive tests, it has been found possible to compact earth fills at about half the cost of obtaining comparable compaction by tamping rollers.

This reduction in cost is a direct reflection of the saving in time. However, it appears probable that the total benefit to a project resulting from the substitution of pneumatic rollers for sheepsfoot rollers may be much greater than the mere saving in the cost of rolling.

Apart from cost, the advantages from the use of pneumatic rollers may be summarised as follows:—

1. A type of roller has been developed that is suitable for the compaction of a wide range of both granular and cohesive soils to the densities required by design criteria.

2. The compaction of materials can be effected at higher moisture content than with tamping rollers; this is of particular importance where materials cannot be dried economically below optimum moisture.

3. Operations may be resumed earlier following rain as the pneumatic rolled fill absorbs less moisture than the tamped fill even though both are rolled with a smooth roller to facilitate drainage before the storm. This feature should be of importance in subtropical climates where rains occur daily. (George E. Bertram, *Engineering News-Record*, Vol. 150, No. 14, April 2, 1953, p. 30, 3 pp., 5 ff.)

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Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Appointments Vacant

The engagement of persons answering Situations Vacant advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18—64 inclusive or a woman aged 18—59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

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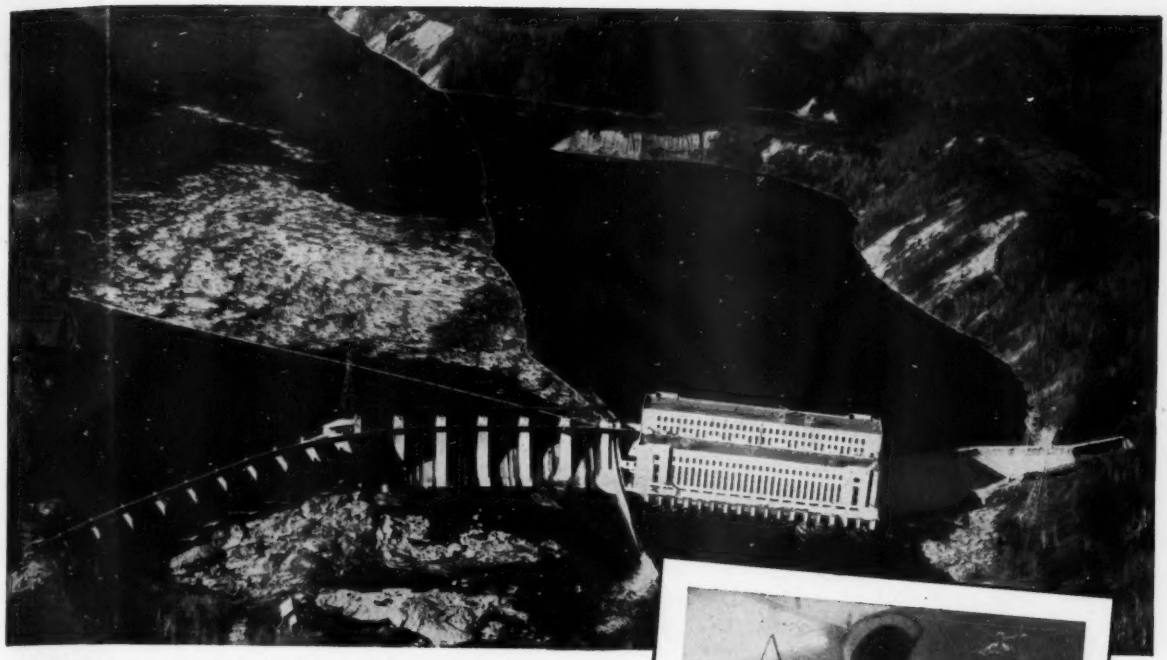
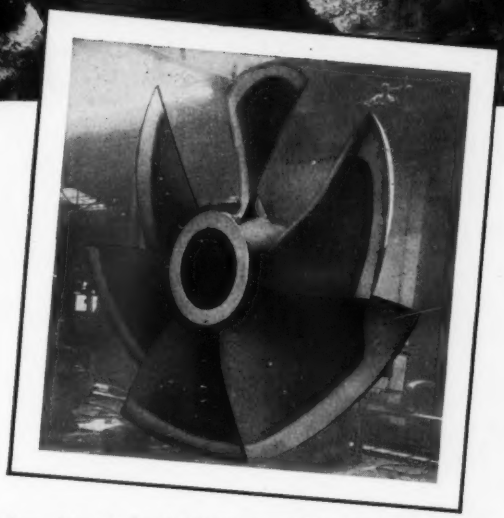


The La Gabelle plant of the Shawinigan Water and Power Company, containing five Dominion fixed blade propeller turbines of 35,000 H.P. each, at 120 R.P.M. under a head of 60 feet.



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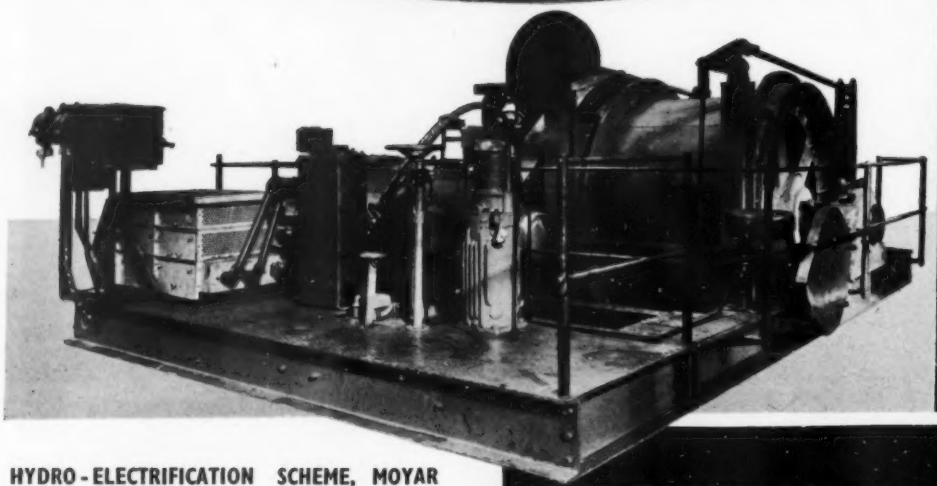

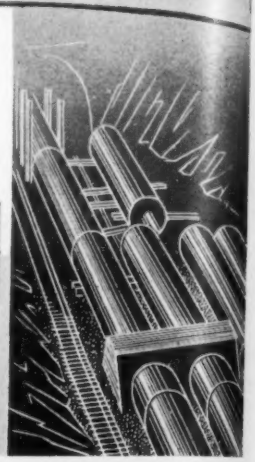

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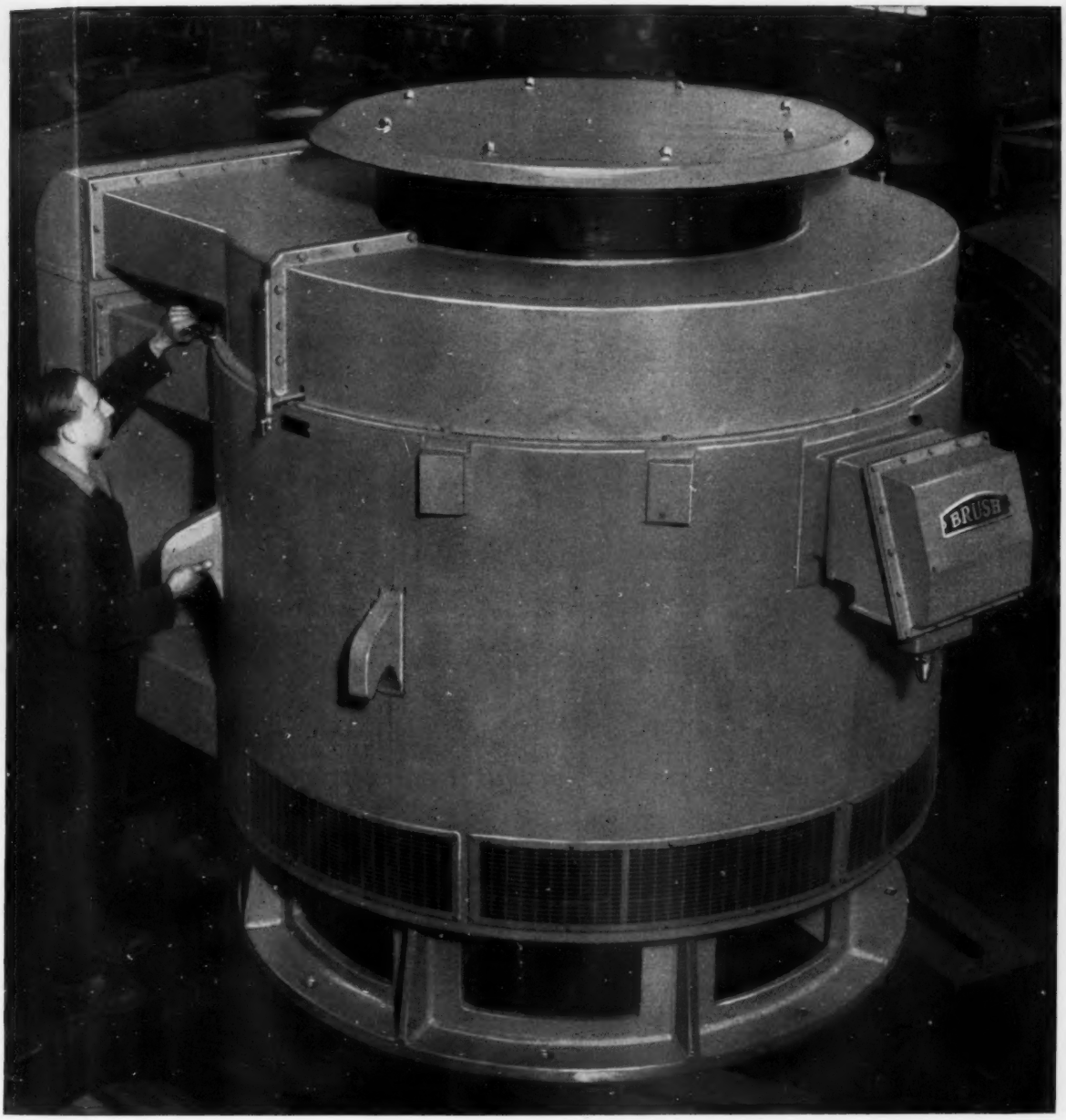

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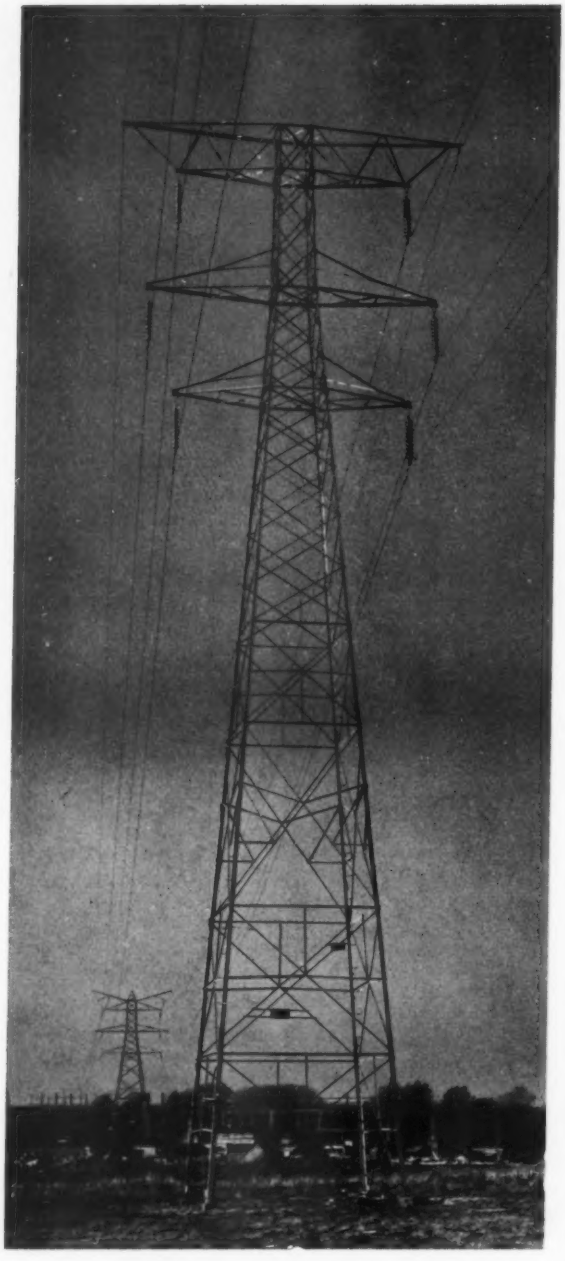

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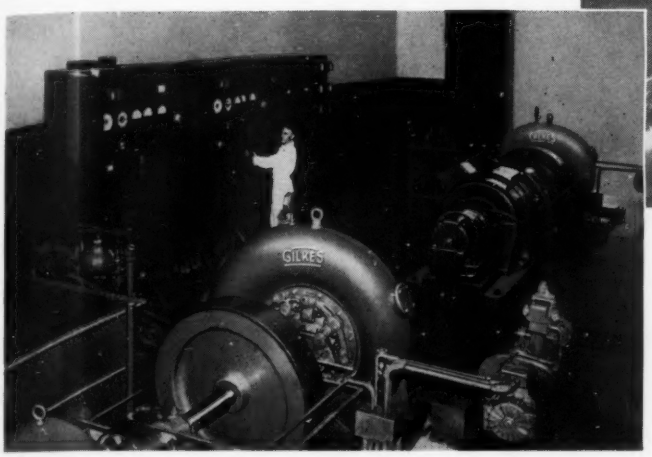

Interior of power station showing the two 200 B.H.P. GILKES *Francis turbines.*

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Power station and intake works

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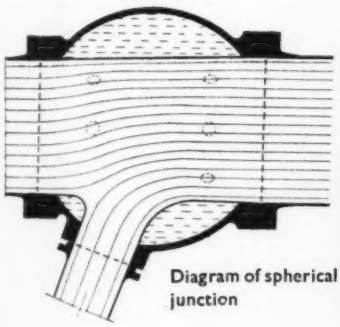
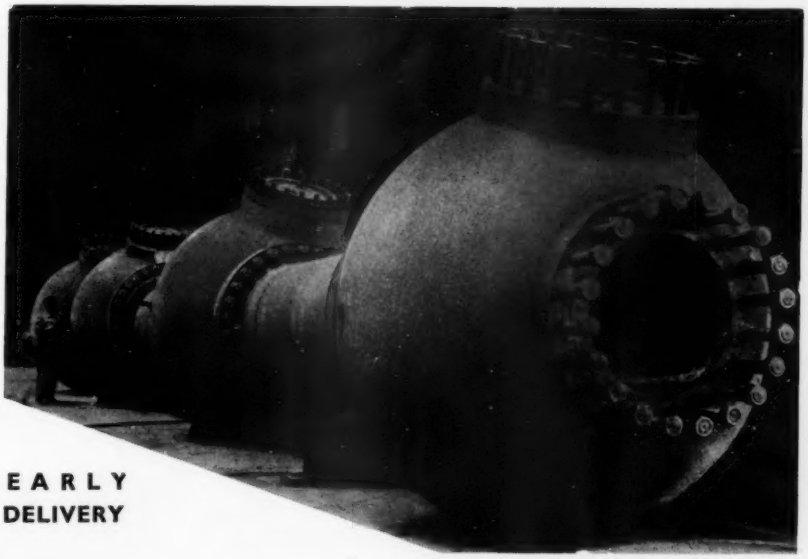


Diagram of spherical junction



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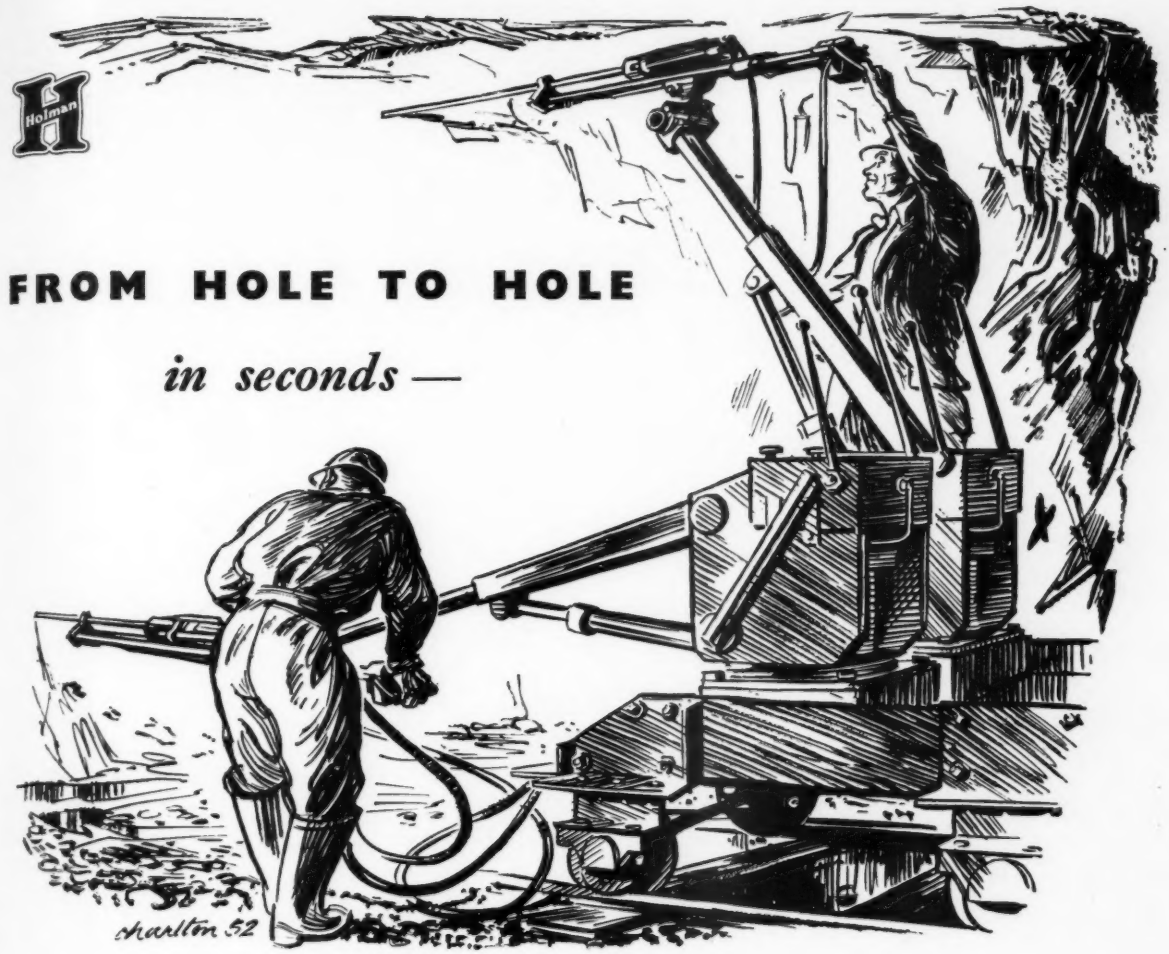

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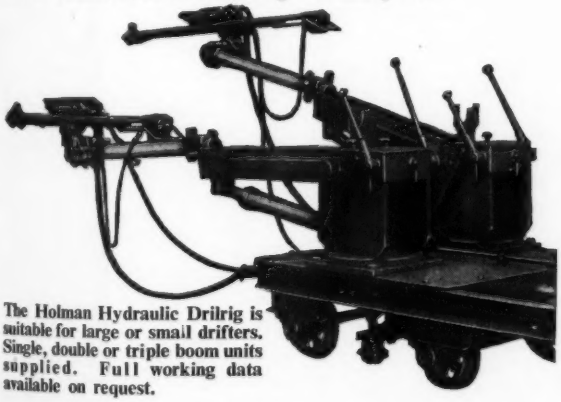

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